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N. W. NEVADA

MICROEARTHQUAKE SURVEY REPORT

for

EARTH POWER CORPORATION

SENTURION SCIENCES, INC.

TULSA, U.S.A.

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Senturion Sciences, Inc., has performed the field work, analyzed the data, and interpreted the results for this task. All data and information resulting from this survey are the property of Earth Power Corporation.

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SURVEY SPECIFICATIONS

REPORT DATE:	September 9, 1977
ARRAY LOCATIONS:	Humboldt County, Nevada, 1. NW NEV 1 - T. 46 N., R. 28 E. 2. NW NEV 2 - T. 44-45 N., R. 27-28 E.
PERIOD OF DATA ACQUISITION:	June-July, 1977
PERIOD OF INTERPRETATION:	July-September, 1977
FIELD CREW:	Senturion Sciences Crew #6
JOB CODE:	Senturion #511
PROJECT SCIENTISTS:	1. NW NEV 1 - Judy Hannah 2. NW NEV 2 - Paul Caton 3. NW NEV Summary - Paul Caton

ABSTRACT

N. W. Nevada microearthquake investigations (NW NEV) were conducted during June and July, 1977, in Humboldt County of Northwestern Nevada. Three significant microearthquake clusters were revealed: Denio (T. 47 N., R. 34-35 E.); Craine Creek (T. 42 N., R. 27 E.), and Thousand Creek (T. 46 N., R. 27 E.) During the two recording periods, magnitude estimates suggest equal amounts of energy/recording day were released from each of the three areas. Apparent velocity measurements indicate typical Western U. S. media velocities at depth. Vp/Vs ratio estimates suggest anomalous, low values near the surface. Denio microearthquakes indicate normal faulting in that area; fault plane solutions for the other two clusters were indeterminate. These microearthquake results suggest good geothermal potential is present in the N. W. Nevada area.

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INTRODUCTION

Two, six-station, 9-km diameter, pentagonal seismometer arrays, Figure 1, were deployed near the northern Nevada boundary in Humboldt County and near the town of Denio. This N. W. Nevada area (NW NEV) has known geothermal activity as evidenced by hot spring activity and anomalous heat flows. The intent of the surveys was to delineate heat source proximities as deduced by microearthquake activity (Figure 1) and to determine relative crustal movements along a NNE-trending fault passing through the array centers. The recording period for the first array, NW NEV 1, was June 16-30, 1977. The second array, NW NEV 2, was centered 16 km southwest of the first array and operated during July 9-20, 1977. Specific array coordinates are given in Appendix A.

During the two short recording periods, three significant microearthquake clusters were detected, Figure 1, and the enclosed plats. Names given to these clusters, their locations, and the number of events within each cluster are:

TABLE 1
SUMMARY OF NW NEV MICROEARTHQUAKE CLUSTERS

Cluster Name	Location	Events Per Cluster
Denio	T.47N., R.34-35E.; Sec. 19,24	39
Craine Creek	T.42N., R.27E.; Sec. 2-3, 10-11	6
Thousand Creek	T.46N., R.27E.; Sec. 22-23, 26-27	26

Each cluster includes "point source" events. That is, each event from a cluster has nearly identical stepout times indicating common locations; only the amplitudes are different for point source events. Sample events from each of these clusters are shown in Figures 2, 3, and 4.

Denio and Craine Creek clusters were detected with the first, NW NEV 1 array, whereas the Thousand Creek suite was observed during NW NEV 2 investigations. Although the number of Craine Creek events are fewer than

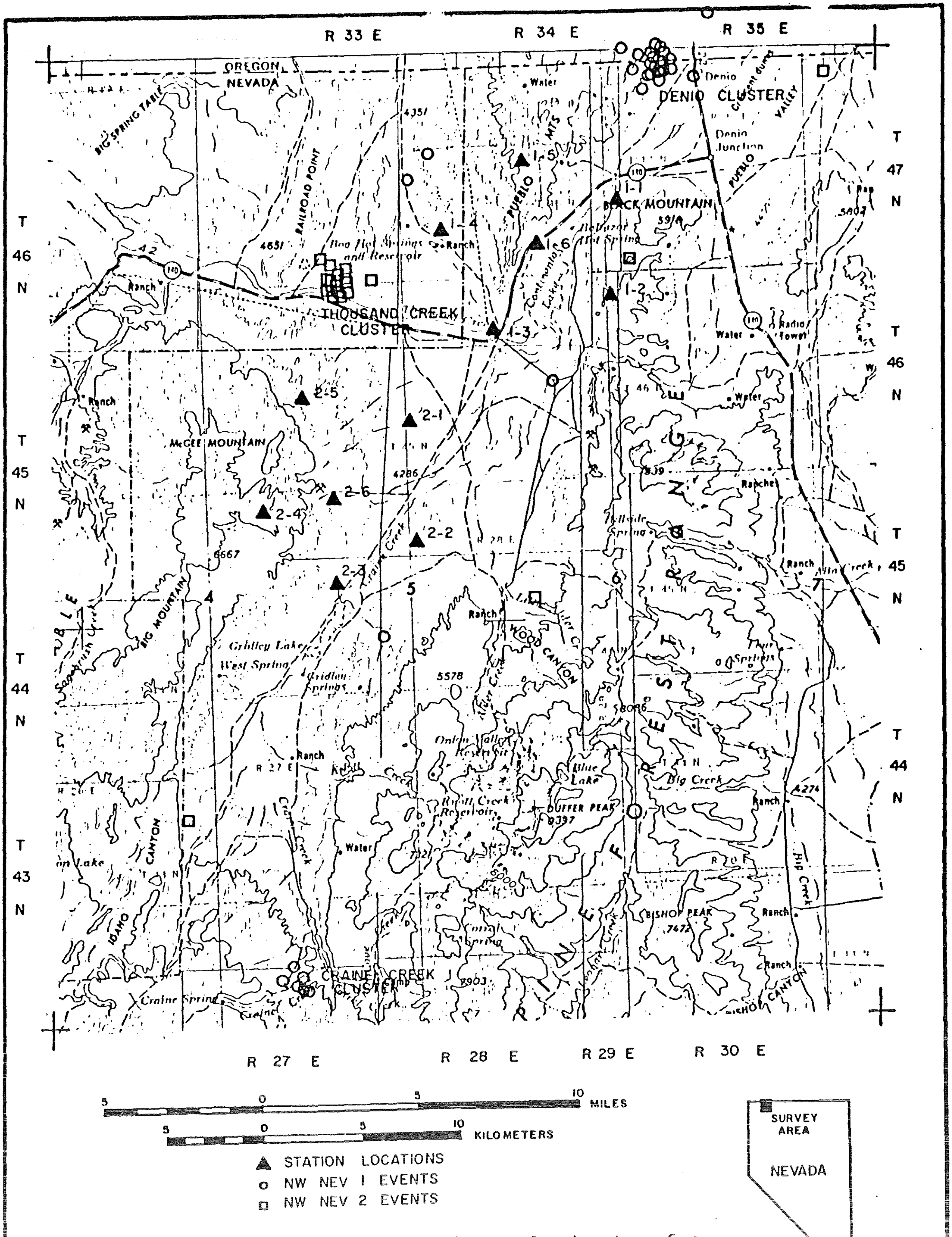


FIGURE 1. NW NEV 1 and 2 station locations and epicenters for microearthquakes detected with both six-station surveys.

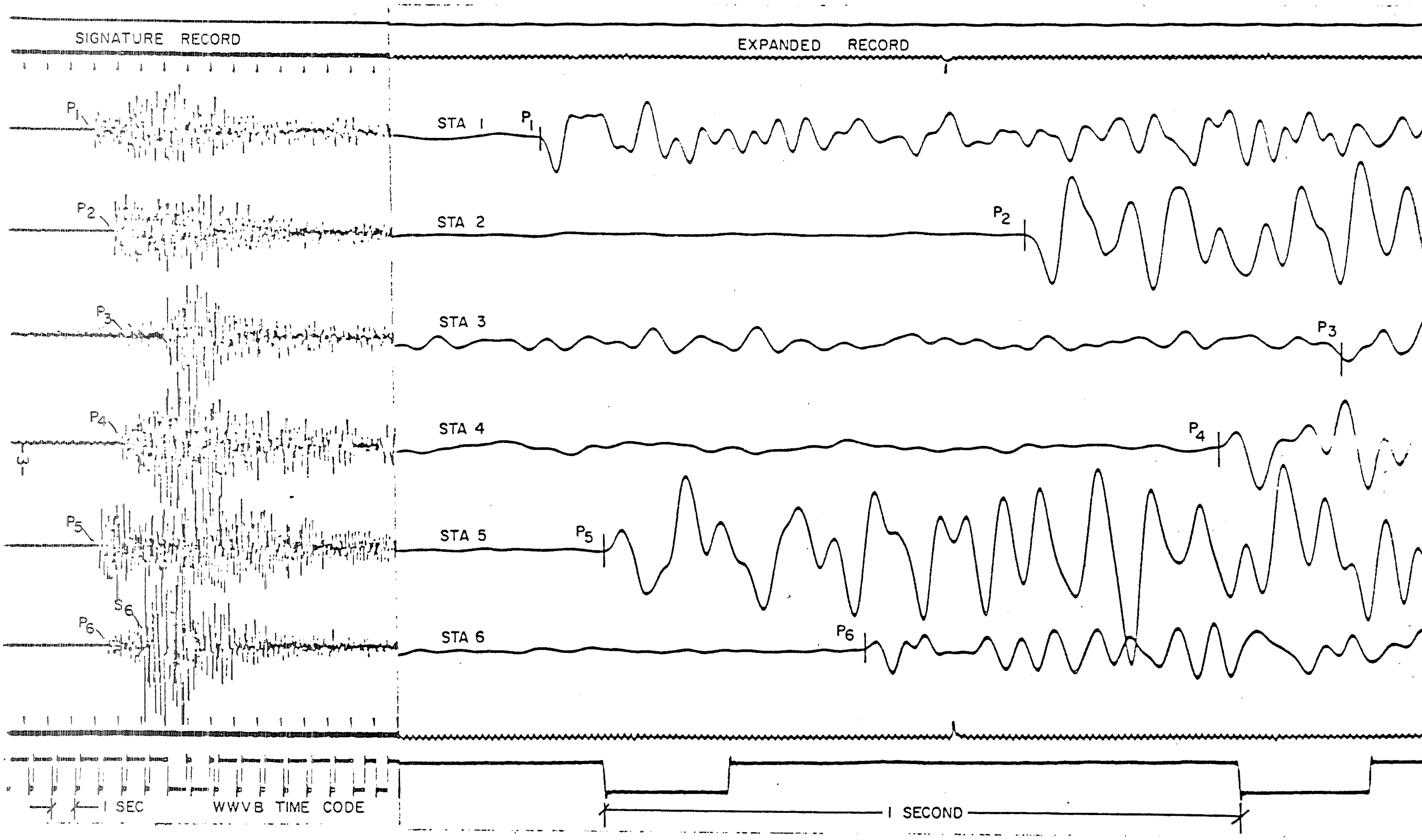


FIGURE 2. Denio cluster microearthquake (NW NEV 1; Event #28). Note different trace deflections at Stations #1 and #5; Station #1 moved downward relative to Station #5. (Trace polarities are in accordance with ground-motion, and all traces have identical polarities as is evident from NW NEV 1 teleseismic data.)

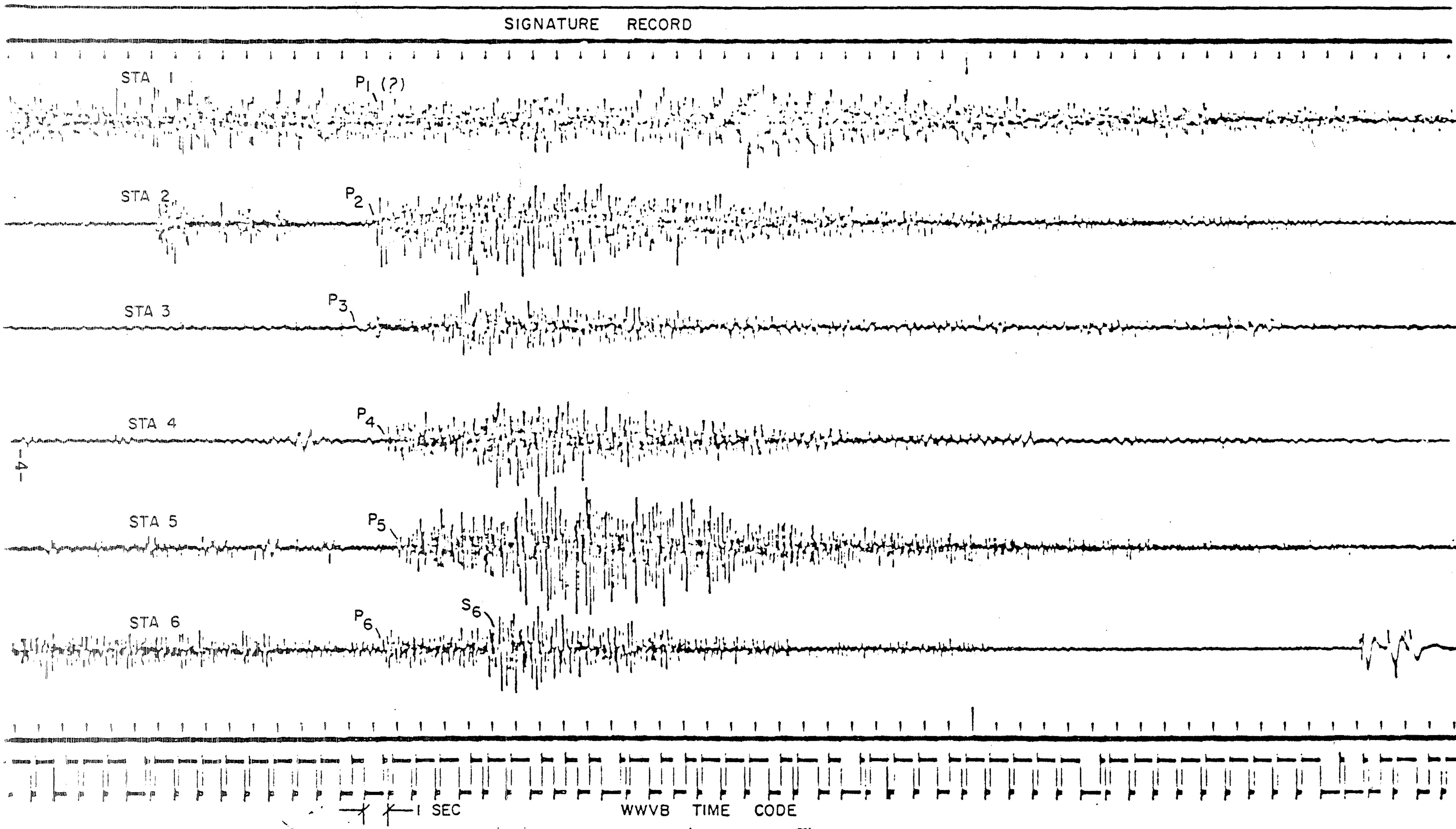


FIGURE 3. Craine Creek cluster microearthquake (NW NEV 1: Event #48).

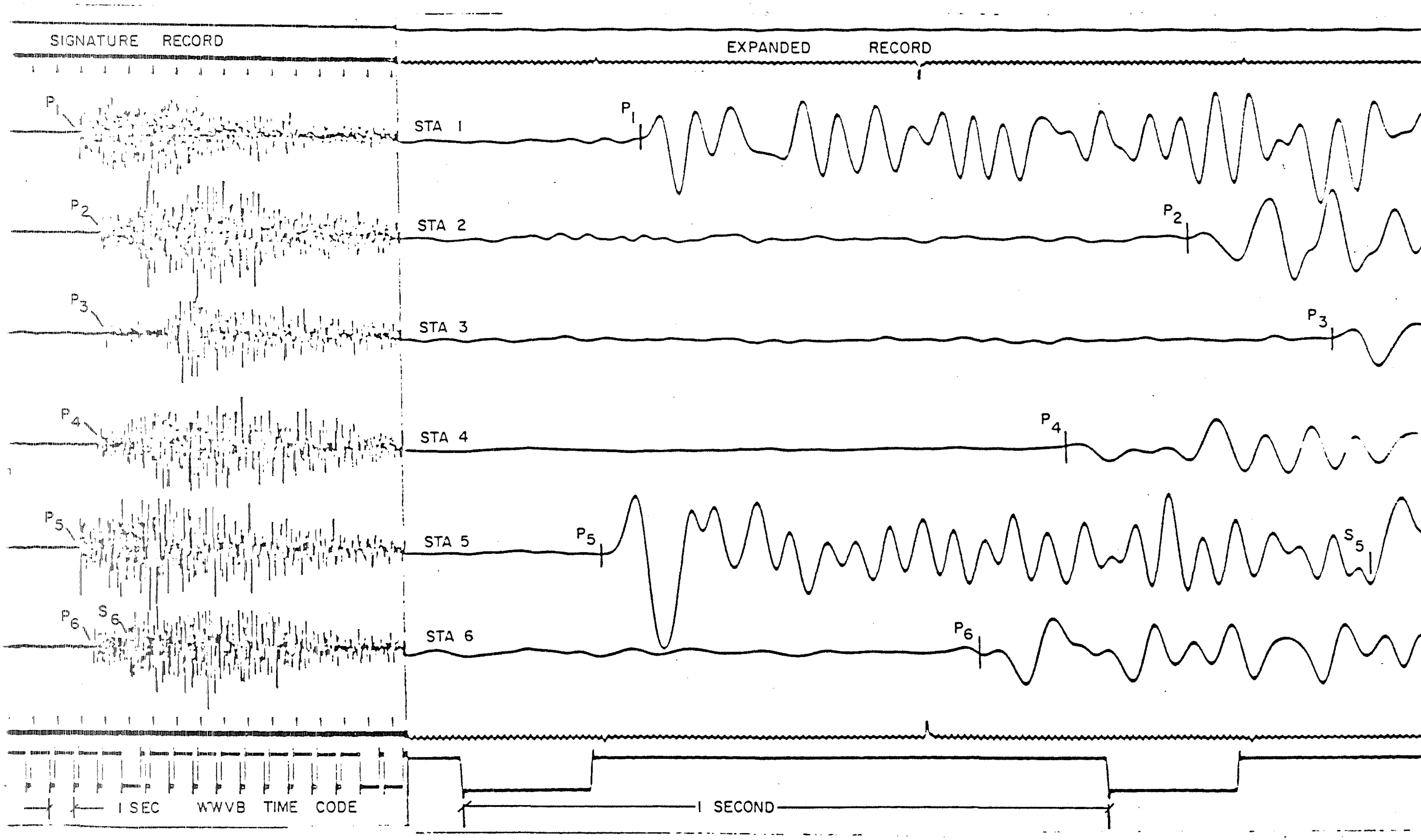


FIGURE 4. Thousand Creek cluster microearthquake (NW NEV 2; Event #22).

those detected at Denio, their significance becomes evident if one considers that the distance to Craine Creek events (38.5 km SSW from the NW NEV 1 array) is 3.5 times greater than the Denio distance (11 km northeast from the NW NEV 1 array center). Seven events not associated with the three clusters also occurred within 10 km of the two array perimeters.

Apparent velocity vector mearurements, Appendix B, were used to deduce location precisions and accuracies, to determine local event position estimates, to assign directions to distant events, and to identify media velocities. Apparent velocity measurements suggest two layers with velocities of 5.6 and 5.9 km/sec overlie the granitic layer Pg_1, which has a velocity of 6.4 km/sec. A deeper layer, Pg_2(?), has a velocity of 7.2 km/sec; this is followed by phase velocities of 8.1 km/sec which are typical for arrivals refracted from beneath the Moho discontinuity. Vp/Vs measurements from 24 Denio and Thousand Creek events indicate Poisson's ratio within array vicinities is $\sim$0.22.

First motions for Denio events (Figure 2) were different, depending on station positions relative to the source. These events could be located with hypocenter location procedures, and first motion plots suggest normal faulting parallel to the NNE linear mountain front. The western Pueblo Mountain Tertiary volcanic sequence moved upward relative to the eastern valley. First motions for Craine Creek and Thousand Creek Clusters were identical at all stations; because these events were beyond the arrays and because trace deflections were identical, relative crustal movements could not be precisely deduced.

Event magnitudes discussed in this report are relative magnitudes, M_r; that is, magnitudes were assigned with a heuristic equation relating signal duration to event magnitude. Therefore, event magnitudes are only known relative to one another and are not tied to the Richter magnitude scale. Relative magnitude assignments are listed with event locations in Appendix B (Tables B1 and B2). The energy released from each of the three cluster areas was $\sim 5 \times 10^{13}$ energy units per recording day.

Teleseismic time delay studies cannot be considered for at least another six months. NOAA is approximately one year behind in publishing locations and origin times for large earthquakes. Figure 5 illustrates a teleseism detected during NW NEV investigations.

The two seismometer arrays and field tape recording equipment were deployed by J. Dillion. Analog data from the six vertical seismometers for each array were transmitted via FM telemetry to a central tape recording site and recorded along with a WWVB time code on seven-channel tape. Each 24-hour tape was played back at the Tulsa office, initially at 10.1 cm/hour. Events selected from these compressed records were expanded at two speeds for analysis: (1) signature records (0.45 cm/sec) for reading WWVB and measuring relative time differences between phases, and (2) expanded records (11.6 cm/sec) for timing phase arrivals.

J. Hannah was the principal analysist for the NW NEV 1 events. P. Caton reviewed this data, located events detected with the NW NEV 2 array, and summarized survey results.

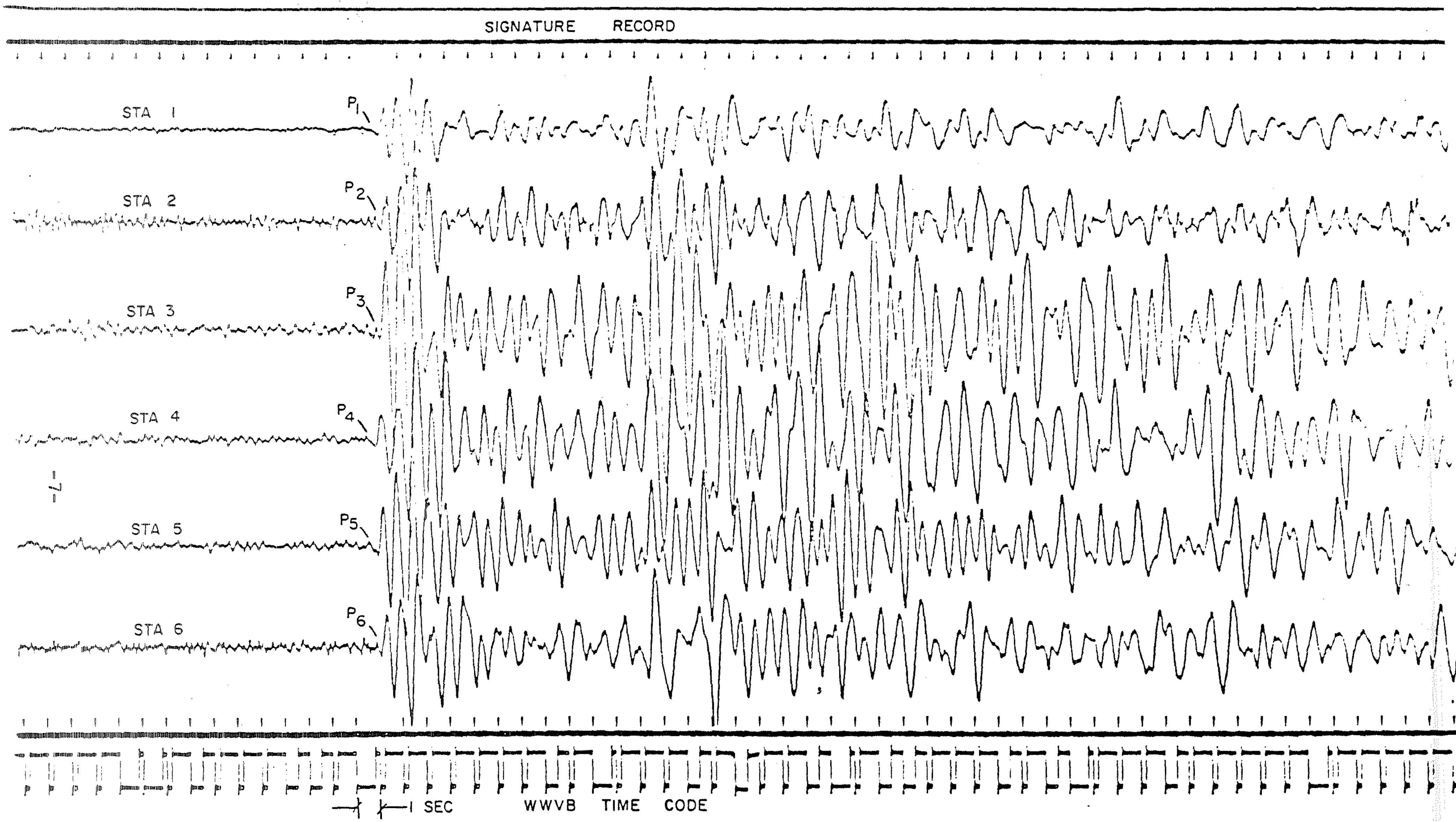


FIGURE 5. Signature record of a teleseism (NW NEV 2; Event #10).

APPARENT VELOCITY VECTOR MEASUREMENTS AND THEIR RELEVANCE TO N. W. NEVADA EVENT LOCATIONS

Plane wave apparent velocity vector measurements are regarded by Senturion to be indispensable aids for improving event locations. Vector information is useful for the following reasons:

1) Imprecise or incorrect arrival times are more easily identified because crustal model assumptions are not included in the solutions.

2) Station correction times can generally be measured; hence array calibration is possible.

3) Good directions to events can be assigned provided events are impulsive and the array is omnidirectional and calibrated.

4) Good media velocity estimates can be deduced from apparent velocities of events which have been critically refracted.

5) For local events, the positions to which epicenter solutions should converge can be determined.

Tables B3 and B4 in Appendix B give final vector solutions for all events. NW NEV 1 results do not include correction times, whereas those for NW NEV 2 include elevation time corrections. For both surveys, least squares apparent velocity results from uncorrected event data indicated station residuals were azimuthally dependent and as large as 50 msec for impulsive events. Using three-station vector comparison techniques in order to resolve difficulties encountered with least squares vector solutions, it was evident that more than two stations required station corrections. This was particularly true for NW NEV 2 results. When more than two stations require significant station corrections (∿20-50 msec), precise station delay times are difficult to resolve. Had known impulsive events been available at distances less than 200 km, improved vector solutions, and hence, location accuracies could have been obtained.

Because difficulties were encountered in determining precise station corrections, NW NEV 1 vector solutions (Table B3) and event locations (Table B1) were calculated without station time corrections. The range of elevations for this array was 207 meters (Appendix A), and the standard deviation of elevation differences from the mean elevation was ±142 meters. In practice, compensation for station delays related to these elevation differences do not significantly affect vector results when arrays are 9 km in diameter.

The NW NEV 2 station elevation range (Appendix A) was 560 meters; the standard deviation of station heights from the mean seismometer elevation was ±210 meters. These values are relatively large for a 9-km diameter array and can have significant effects on vector solutions and location determinations. Therefore, correction times were calculated by choosing 4.6 km/sec as the velocity to correct arrivals to the mean seismometer elevation. These elevation time corrections did give better vector solutions, but improved solutions could only be obtained by reducing Station #1 weighting to ¼ the normal value. Using 16 impulsive distant events at different azimuths for array calibration purposes, applying station elevation time corrections, and reducing Station #1 weighting, average residuals for Stations 2-6 were within 5 msec but deviated within 20 msec for events at different azimuths. Station #1, which had least effect on vector solutions (because of the reduced weighting), had average residuals of -5 msec, but deviated within ±60 msec, depending on event azimuth.

Reviewing apparent velocity tables in Appendix B, velocities for events greater than 20-km distant can be loosely lumped into the following groups:

TABLE 2
N. W. NEVADA APPARENT VELOCITY GROUPS SELECTED FROM TABLES IN APPENDIX B

Group	Ap. Vel. Range, km/sec	No. Of Events Within Group	Avg. Ap. Vel. For Group, km/sec	Comments
1	5.61-5.64	2	5.6	Upper Layer
2	5.85-6.01	5	5.9	Layer over Pg_1
3	6.07-6.61	19	6.4	Granitic Layer, Pg_1
4	6.77-7.56	10	7.2	Pg_2(?)
5	7.86-8.26	7	8.1	Layer beneath Moho, P_n
6	8.75+	12	8.8+	Velocities $>P_n$

The first velocity group in Table 2, loosely defined by two events with a velocity of ∿5.6 km/sec, was chosen because this velocity was also observed between station pairs for a few local Denio events. The second group seemed evident from primary and secondary P phases for events at respective 35- and 85-km distances. The third group, Pg_1, is typically observed in Western U. S. and defines the granitic layer velocity for which Senturion's arrays have been dimensioned to measure. Another Pg_2 layer seems evident when secondary P arrivals were used to time distant events. P_n was definitely observed for events at distances >200 km, and the last suite includes teleseismic velocities.

Vp/Vs ratios were determined from 24 of the better Denio and Thousand Creek events; reduced Wadati diagrams are shown in Figures 6-8. Data from seven Denio events, Figure 6, suggest Vp/Vs = 1.70 ± .05, whereas 17 events from the Thousand Creek cluster, Figure 7, indicate Vp/Vs = 1.66 ± .04. These measured ratios seem reasonable; the two data sets were timed by different persons, the events were at similar distances from the

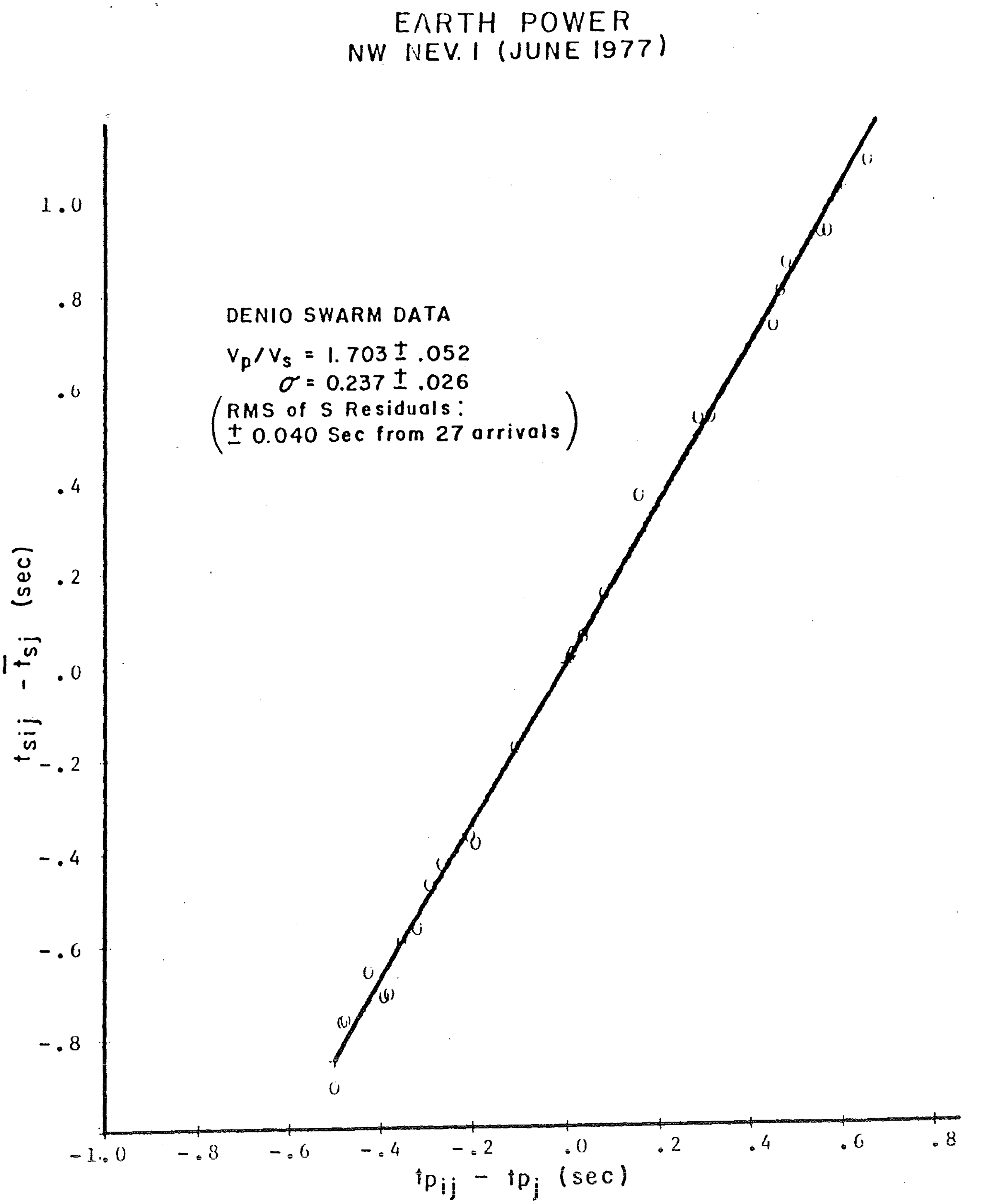


FIGURE 6. Reduced Wadati diagram for Vp/Vs determinations from seven Denio events. tp_{ij} and ts_{ij} are the respective P and S arrival times at the ith station from the jth event. $\bar{t}_{pj}$ and $\bar{t}_{sj}$ are the mean P and S times for the jth event.

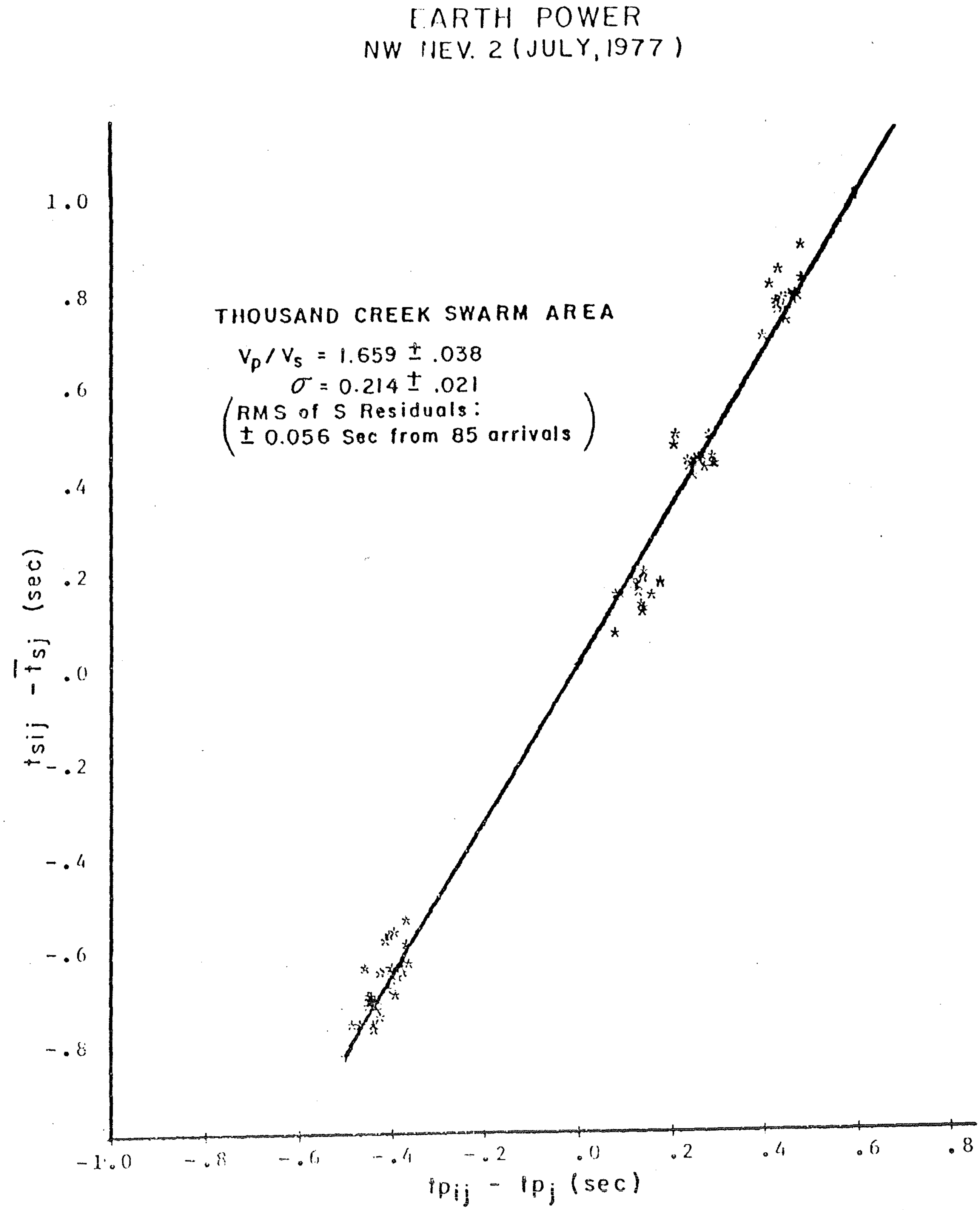


FIGURE 7. Reduced Wadati diagram for Vp/Vs ratio determinations from 17 Thousand Creek events.

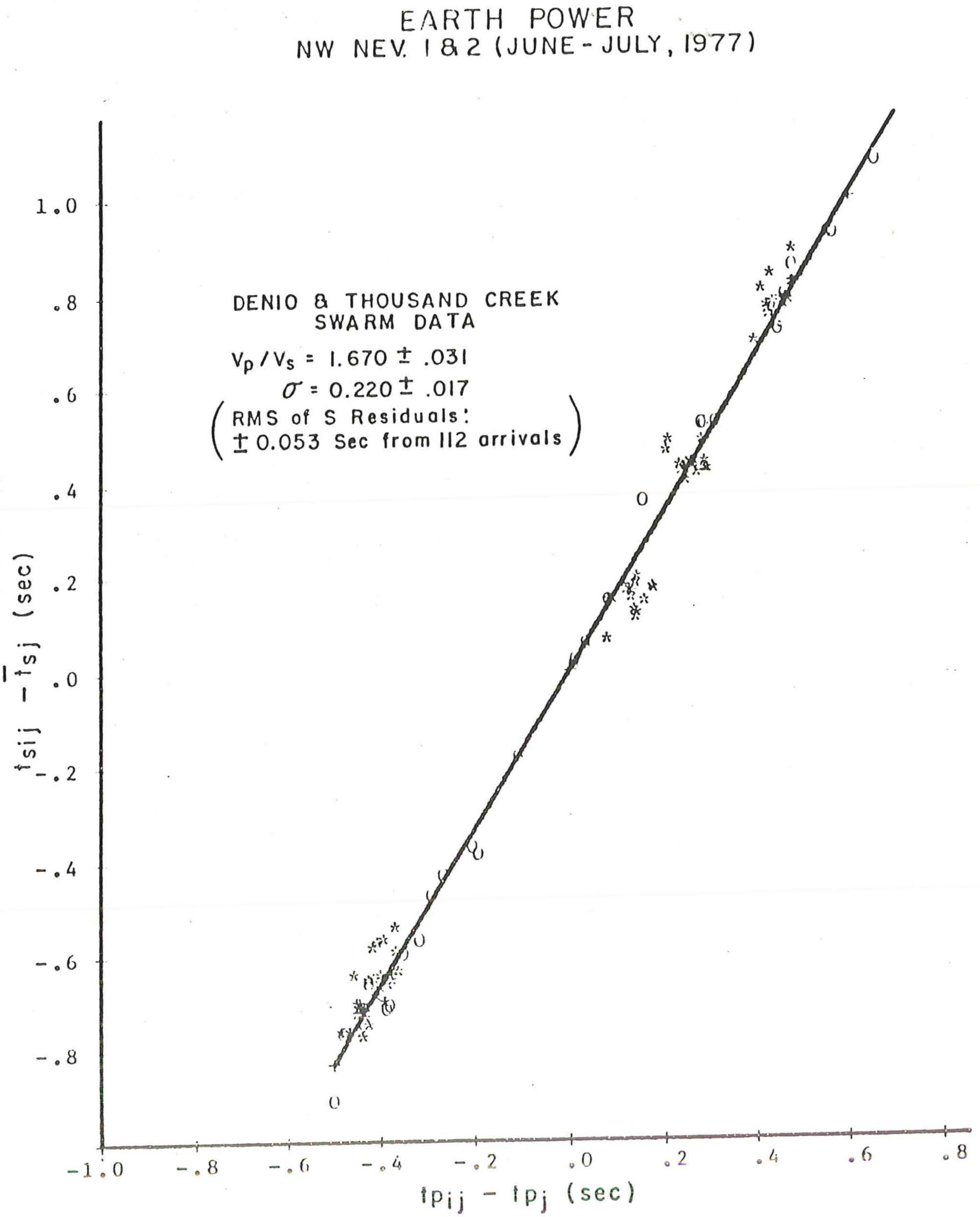


FIGURE 8. Reduced Wadati diagram for Vp/Vs ratio determinations from 24 Denio and Thousand Creek events.

measuring arrays, and the ratios are within two percent. Reviewing ratios for individual events, selected Denio events range from Vp/Vs = 1.64 to 1.77, and those from the Thousand Creek cluster range from Vp/Vs = 1.58 to 1.76. The combined data in Figure 8 indicates Vp/Vs = 1.67 ± .03, or Poisson's ratio, σ, is 0.22 ± .02 as determined from 24 events.

Apparent velocity vector divergence and velocity variation maps for hypothetical NW NEV 1 events are shown in Figures 9 and 10. These distributions are, respectively, the standard deviations of vector directions and velocity deviations for hypothetical hypocenters. Beyond the array perimeter, vector divergence is slightly affected by the choice of hypothetical earth models or focal depths. Velocity variation distributions are, however, sensitive to focal depths such that for shallow foci, velocity variations quickly approach small values just beyond array perimeters. When velocity variation is less than 10% of the apparent velocity, unique focal depths cannot be determined.

Selecting a few Denio events from Appendix B (Table B3), Events #74, #79, and #80, the mean vector direction and divergence values are 35° ± 11°, and mean velocity values are 6.5 ± 1.1 km/sec. The 11° vector divergence value suggests Denio events could be 6.5 km from Station #6 at 35° azimuth in Figure 9. However, by plotting selected subarray vector directions for Denio events, they did not precisely intersect within a small region; this indicated that observed vector divergence was a consequence of imprecise times and uncorrected station delays.

The observed velocity variation, 1.1 km/sec, indicates Denio events are further than 6.5 km from the array center, Figure 10. Using the average S-P interval for these events (1.64 sec), and assuming surface foci on a half-space with Vp = 6.4 km/sec and Vp/Vs = 1.73, the S-P interval suggests Denio events could be 15 km from the array. The final epicenter positions for Denio events, when calculated with hypocenter location procedures, 11 km at 35° azimuth, lie between the least distance defined by vector divergence (6.5 km) and the maximum distance (15 km) for hypothetical surface foci. Thus, distances to Denio foci, which occurred at depth, have been well established.

NW NEV 2 apparent velocity vector distribution plots are given in Figures 11-13. These plots were necessary to determine reasonable locations for the Thousand Creek cluster. For northern events at ∿10-km distances, vectors have smaller divergence values than is the case for Denio events relative to their array. Selecting three NW NEV 2 events, #21, #22, and #23 (Appendix B, Table B4), the average vector direction is 357.0° ± 4.5°, and the apparent velocity is 8.1 ± 0.5 km/sec. Although Figure 11 suggests Thousand Creek events could be ∿15 km north of the array, reduced weighting for Station #1 times causes vector divergence values of 4.5° to be ∿5 km less than is shown. The primary concern for Thousand Creek events was the relatively high apparent velocity, 8.1 km/sec. These events had to be near the array in view of the observed apparent velocity, Figure 13, but were probably deeper than those at Denio. With low divergence values (∿4.5°) and high apparent velocities (8.1 ± 0.5 km/sec) the Thousand Creek events could not be located with hypocenter location procedures. These events were located by using vector directions

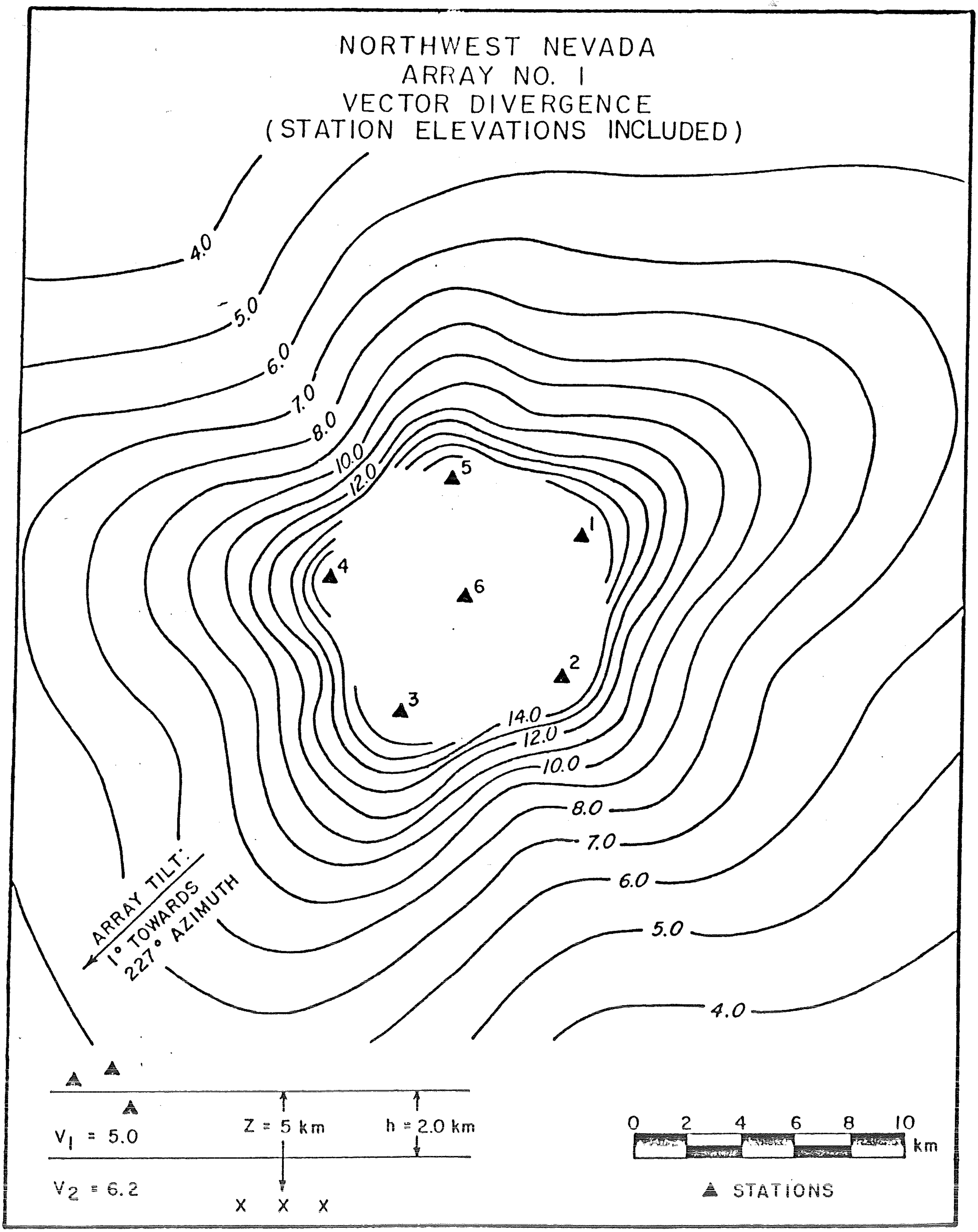


FIGURE 9. Apparent velocity vector divergence distributions for hypothetical foci beneath the NW NEV 1 array.

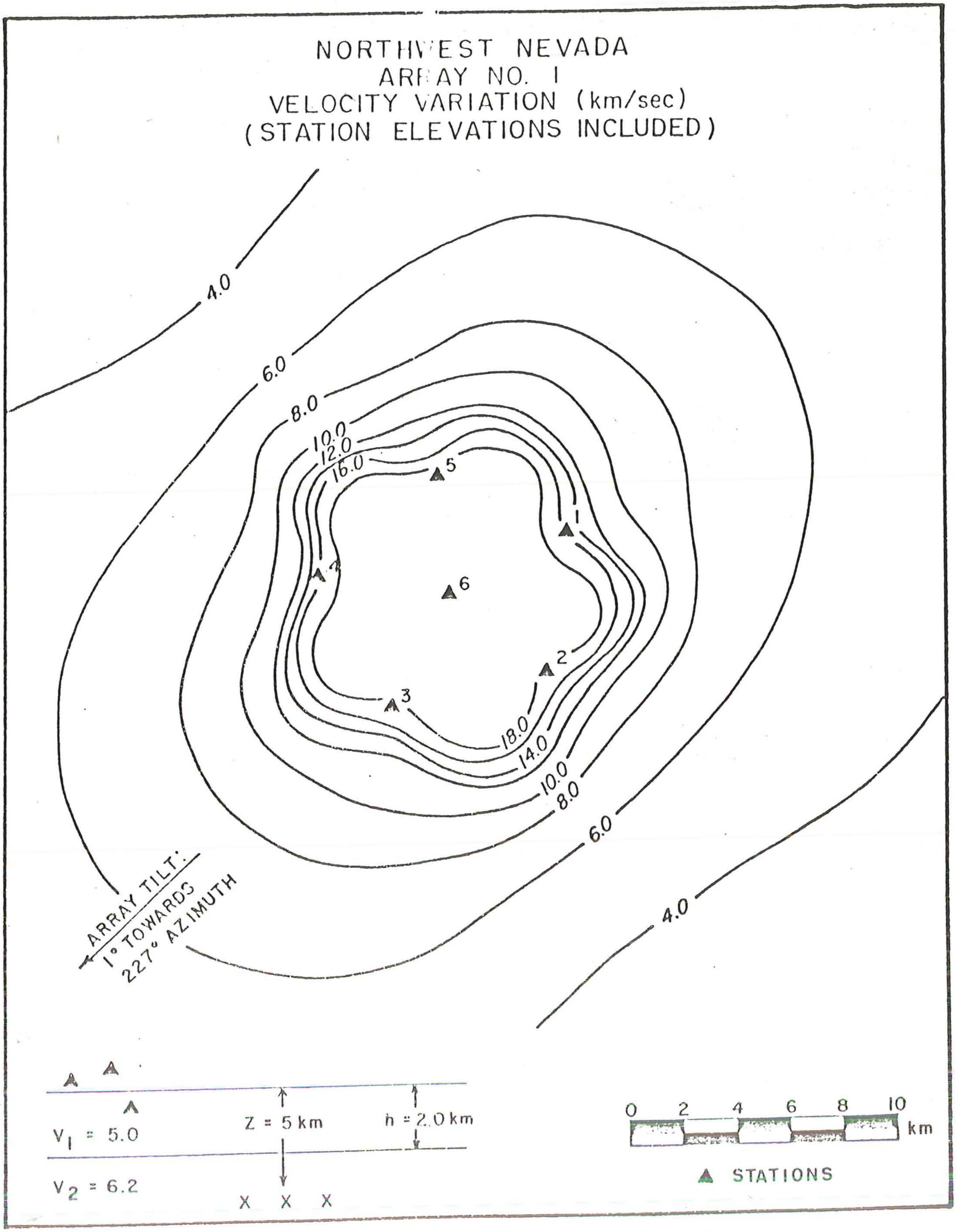


FIGURE 10. NW NEV 1 velocity variations for hypothetical events.

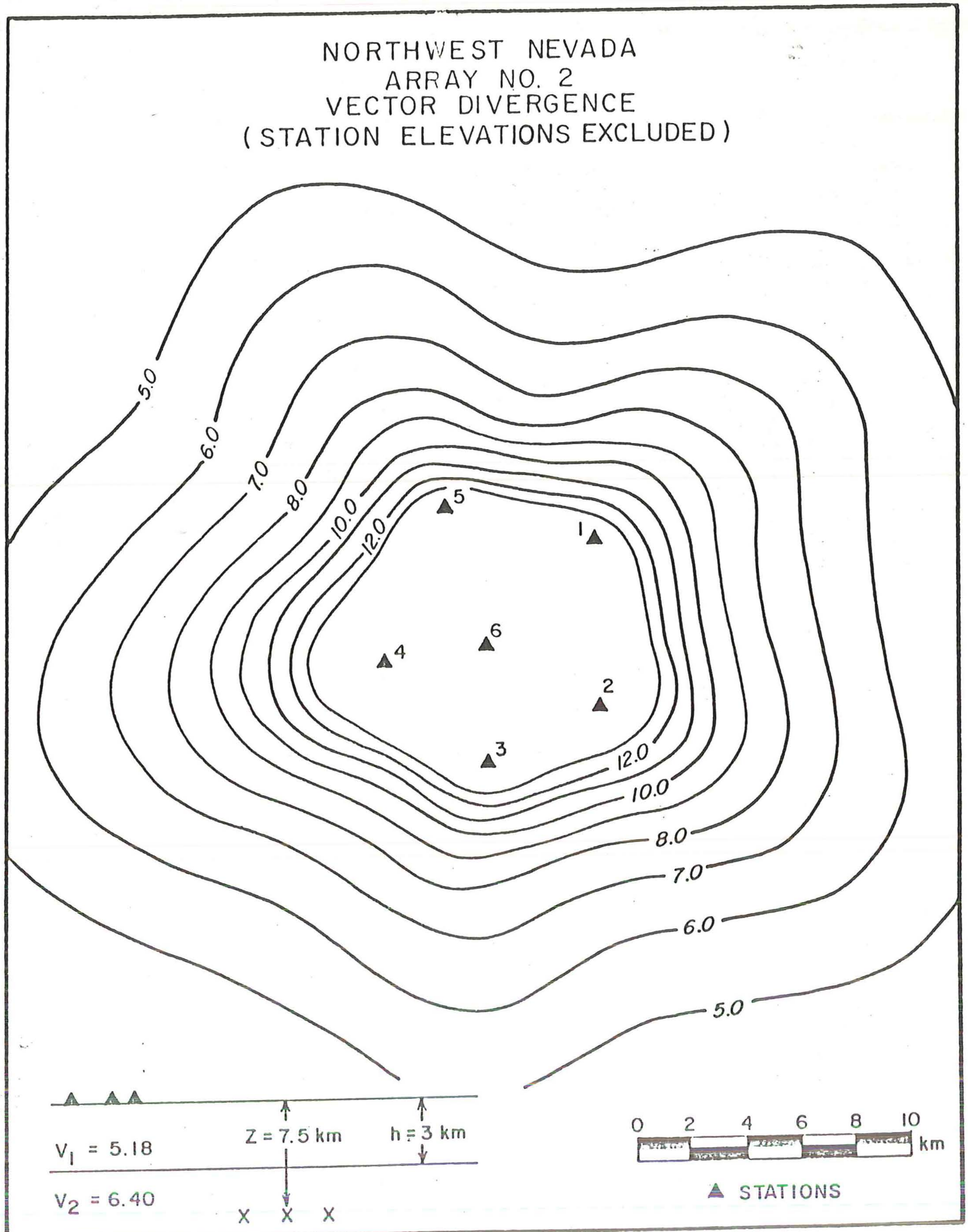


FIGURE 11. Apparent velocity vector divergence distributions for hypothetical foci beneath the NW NEV 2 array.

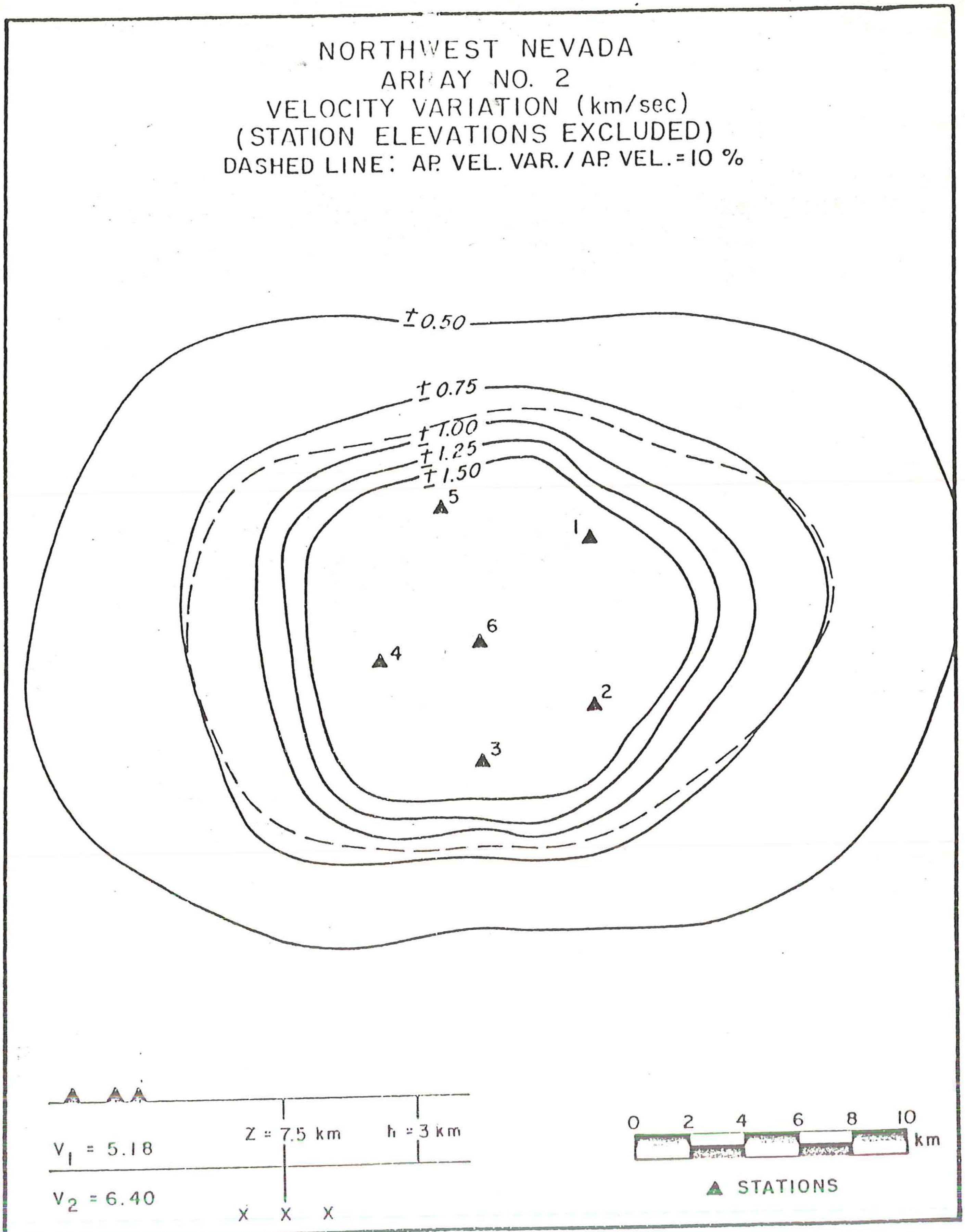


FIGURE 12. NW NEV 2 velocity variations for hypothetical events. The dashed, 10% line indicates the maximum distance at which focal depths can be uniquely determined for events at 7.5-km depths.

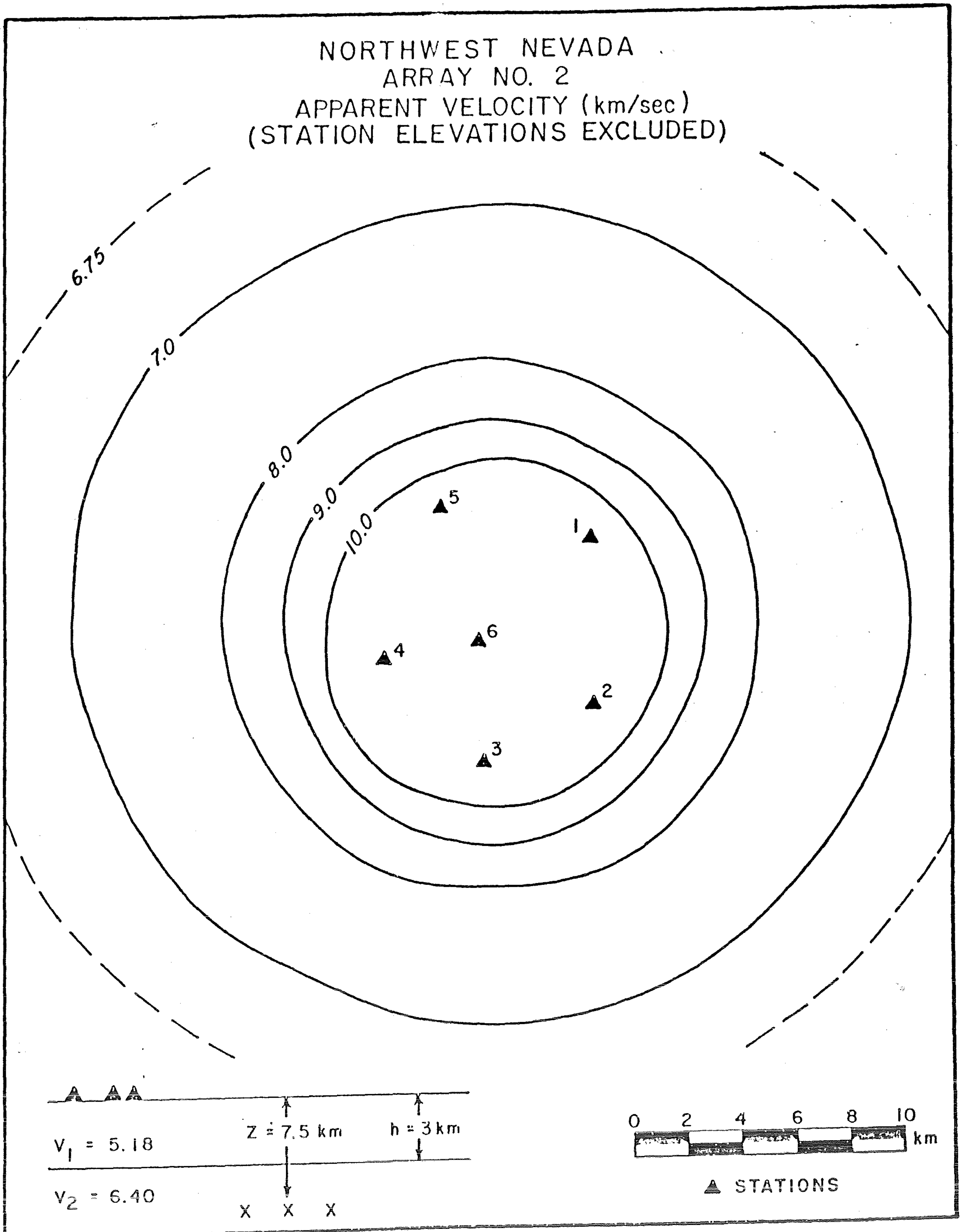


FIGURE 13. NW NEV 2 apparent velocity distributions for hypothetical foci at 7.5-km depths beneath the NW NEV 2 array.

to assign azimuth, and an S-P distance chart derived for hypothetical foci at 7.5-km depths within the crustal model shown in Figures 11-13. Vp/Vs was set at 1.70.

LOCATION ACCURACIES AND PRECISIONS

Fundamental to the N. W. Nevada task is the determination of location accuracies and precisions. The ultimate goal of this investigation is to find the most favorable geothermal targets as deduced from microearthquake locations. The previous apparent velocity vector section discussed methods for assigning positions for Denio and Thousand Creek clusters and gave reasons why distances were nearly correct. Assuming both clusters were from separate points, precision estimates of cluster scatter suggest distances were known within ± 2.5 km, and directions were within ± 15°; however, array directional accuracies remain to be established.

After all results were calculated and tabulated, Figures 14-19 were plotted. These include seismicity versus calendar day, time of day, and azimuth. From the azimuthal distributions, Figures 16 and 19, many southeastern events were noted to occur during working hours when comparing respective Figures 15 and 18. These events were Battle Mountain, Nevada, blasts; however, because they occurred on different days, they were independently timed without recognizing corresponding events. The blast record, Figure 20, was detected with the NW NEV 2 array, and is exceptionally clean compared to most blast records; the seismogram is definitely better than those blasts recorded during NW NEV 1 investigations. In the latter case, wind and cultural noise typically reduced detectability at more than one station; only one blast, Event #38 (Table B3), was recorded on all six of the NW NEV 1 array stations. Table 3 summarizes directions and distant assignments calculated for the blasts, and gives errors relative to true blast directions and distances.

TABLE 3
SUMMARY OF ASSIGNED BATTLE MOUNTAIN BLAST LOCATIONS
COMPARED TO ACTUAL LOCATIONS

(The directions and distances to Battle Mountain blasts take precedance over those listed in the Appendix B Tables.)

NW NEV 1 Azimuth and Distance to Battle Mountain: 139° @ 245 km
NW NEV 2 Azimuth and Distance to Battle Mountain: 133° @ 245 km

NW NEV 1			NW NEV 2		
Event No.	Observed Azimuth	Assigned Distance, Km	Event No.	Observed Azimuth	Assigned Distance, km
2	132.7°	230	28*	134.4°	193
38*	125.4°	311	46*	121.6°	169
43	127.3°	231	47*	124.2°	169
68	125.7°	343	52*	134.0°	208
21	120.5°	225	56	142.4°	258
			57	123.4°	242
			60	120.3°	242
Avg.	126.3±4.4°	268±55	Avg.	128.6±8.3°	211.6±36.5
Error	-12.7°	+23 km	Error	-4.4°	-33 km

*Asterisks denote solutions with six stations.

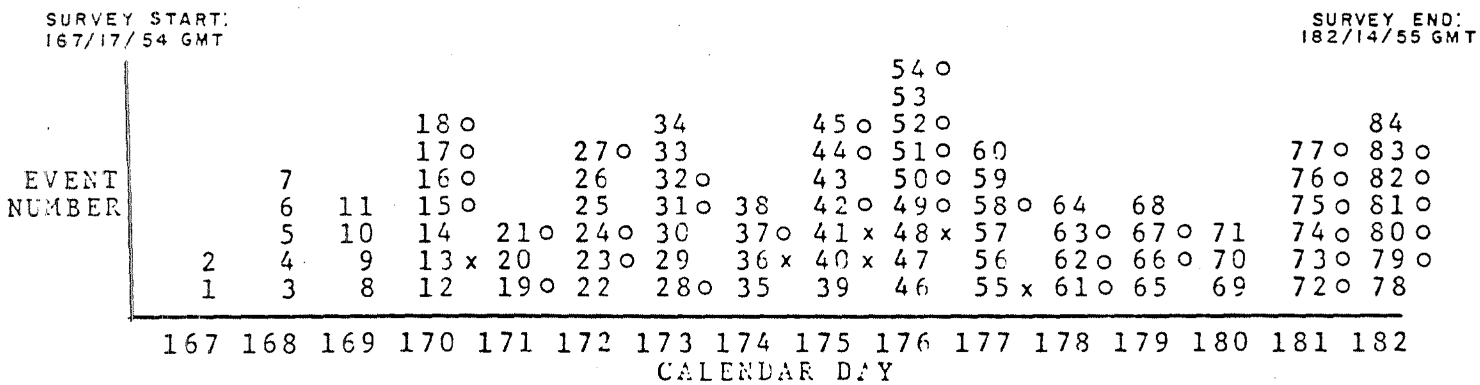


FIGURE 14. NW NEV 1 seismicity versus calendar day. Circles (o) after event numbers identify Denio microearthquakes, and crosses following numbers denote Craine Creek events.

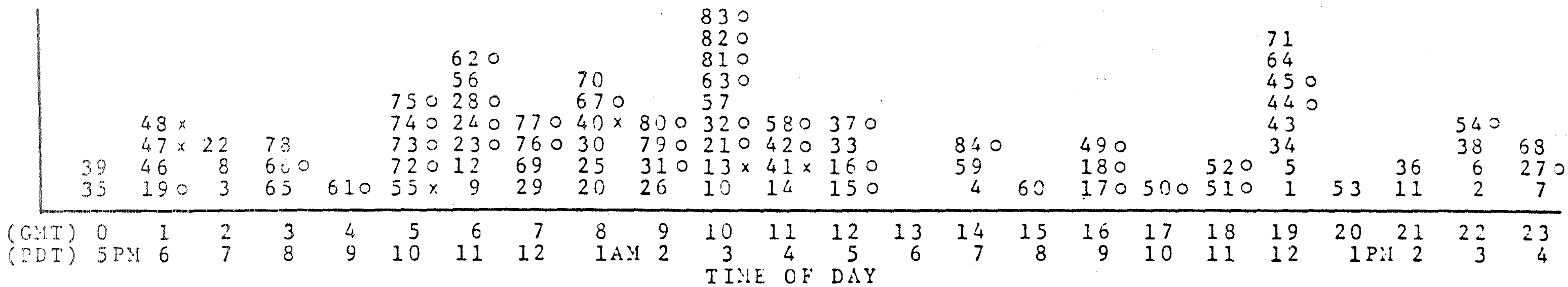


FIGURE 15. NW NEV 1 seismicity versus time of day. (Circles = Denio events; Crosses = Craine Creek events.)

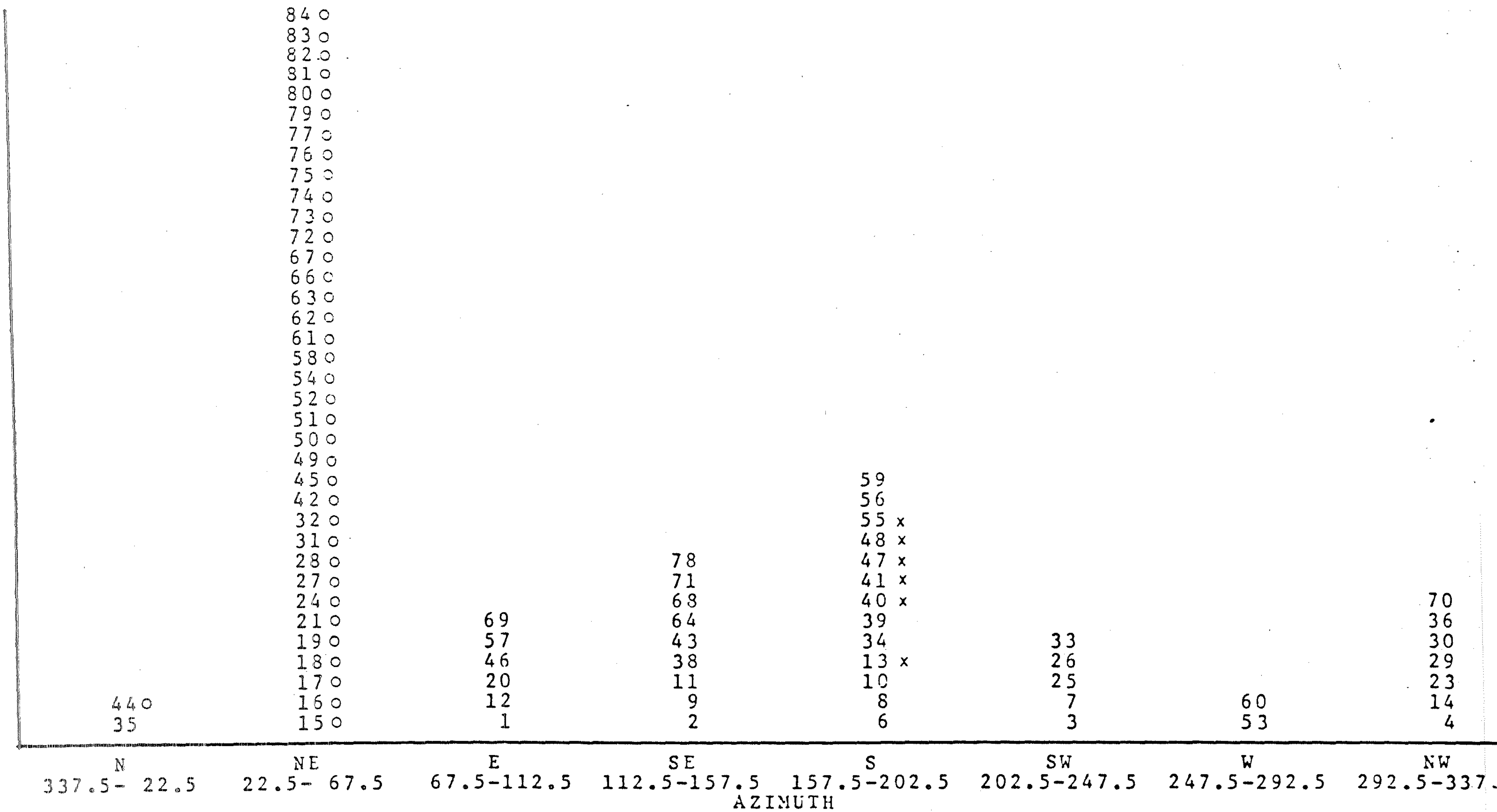


FIGURE 16. NW NEV 1 seismicity versus azimuth. (Circles = Denio events; Crosses = Craine Creek events.)

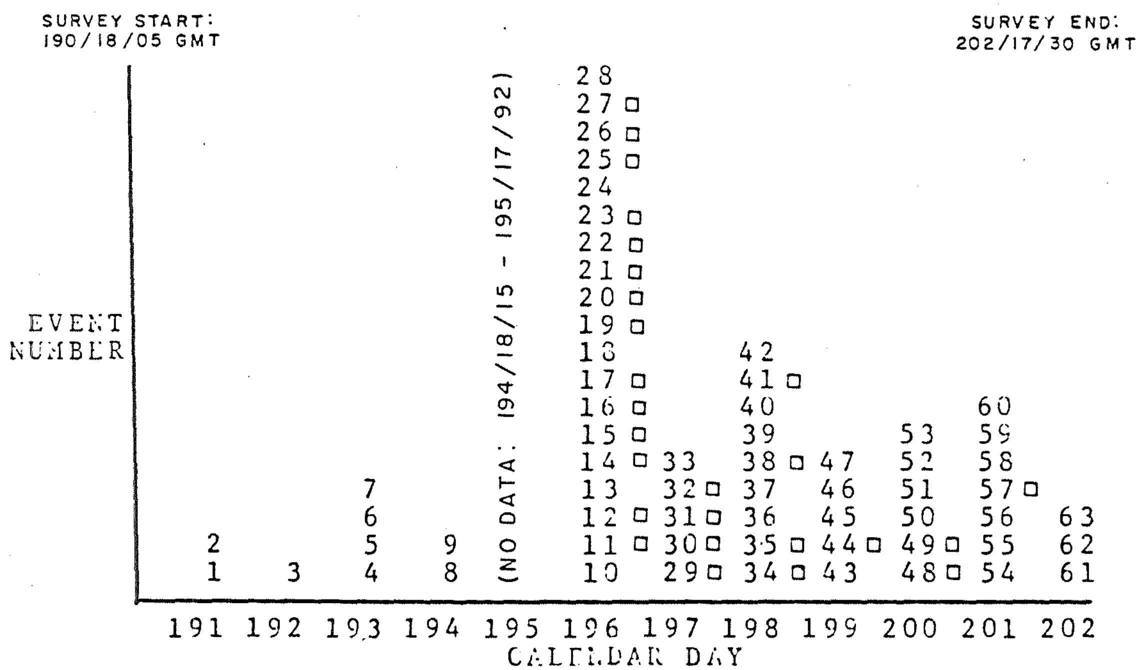


FIGURE 17. NW NEV 2 seismicity versus calendar day. Squares (□) following event numbers denote Thousand Creek microearthquakes.

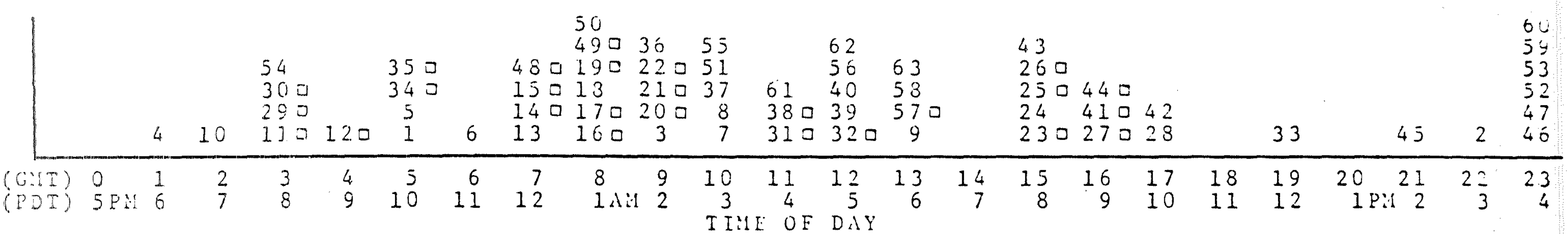


FIGURE 18. NW NEV 2 seismicity versus time of day. (Squares = Thousand Creek events.)

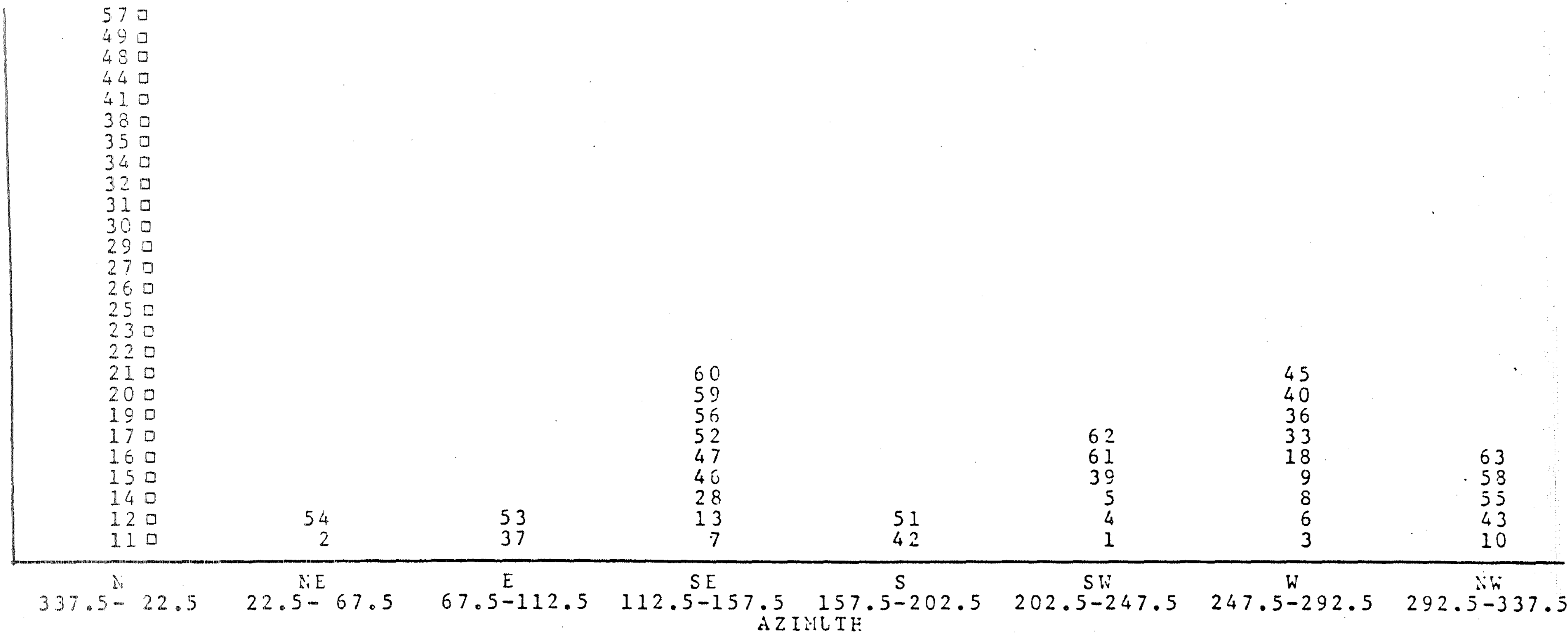


FIGURE 19. NW NEV 2 seismicity versus azimuth. (Squares = Thousand Creek events.)

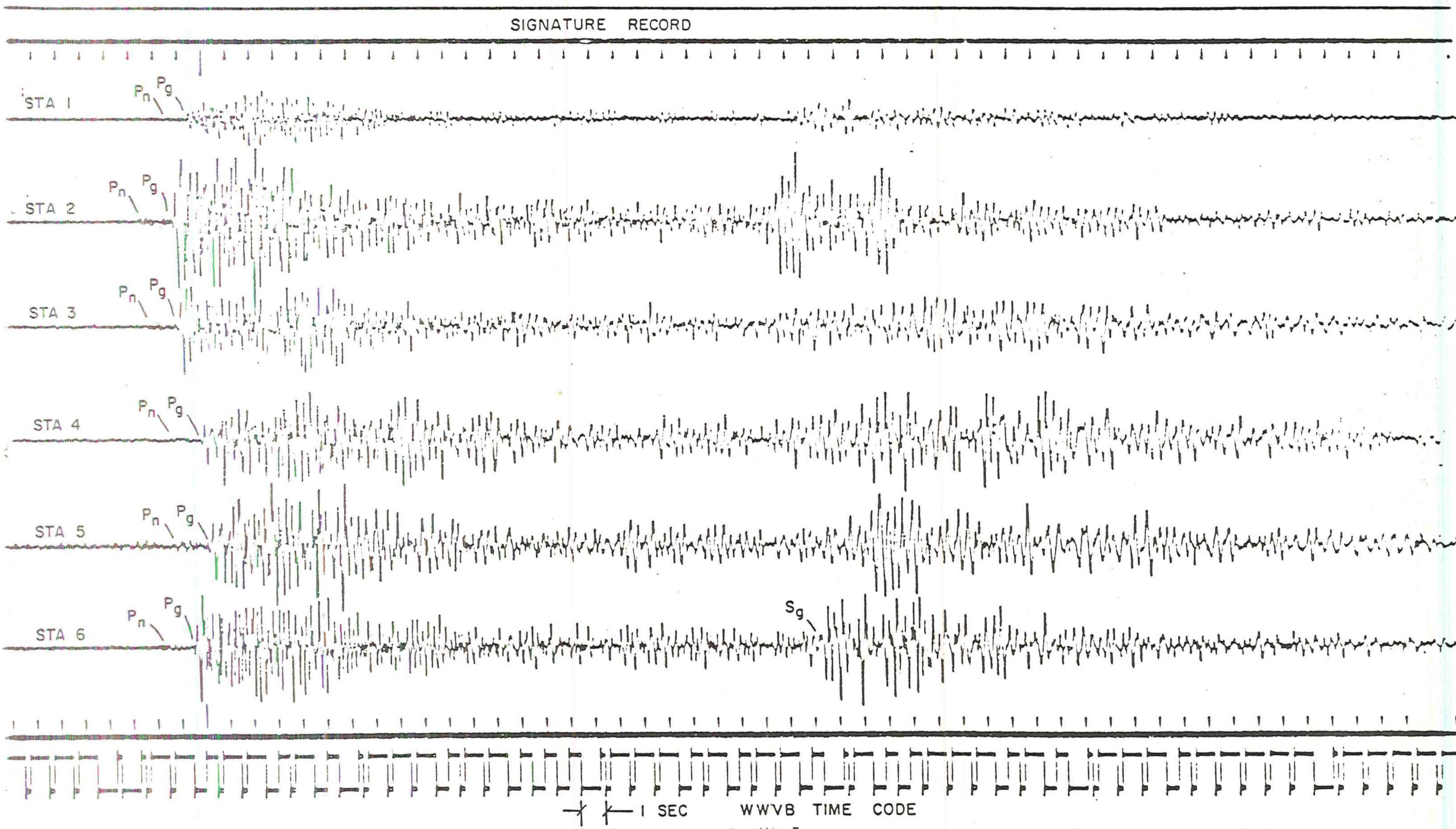


FIGURE 20. Battle Mountain blast detected with the NW NEV 2 array (Event #28).

Directional error for the five NW NEV 1 blasts was 12.5° ± 4.4° less than the true direction; the seven blasts detected during NW NEV 2 investigations were -4.4° ± 8.3° relative to correct blast azimuths. Errors in distance assignments were large: + 23 ± 55 km and -33 ± 37 km for the respective NW NEV 1 and 2 arrays. At ∿250-km distances it is not surprising that distances are in error by 20%. S phase identification is difficult, and one is likely to choose an incorrect velocity for distance assignments. Although NW NEV 1 blasts are in error by -12.7°, it is doubtful that 13° should be added to all NW NEV 1 events; the blasts were emergent. Furthermore, NW NEV 1 subarray vector solutions for local events (S-P < 5 sec) did not show evidence that mean vector directions were in error by 13°. The primary point of this discussion is that array directional accuracies were relatively good to distances of 250 km; from previous experience, distance assignments to 200 km have typically been within 10%.

MAGNITUDE DETERMINATIONS

Relative magnitudes, M_r, were calculated from event durations of local events. Because Senturion's seismometer system has not been calibrated for precise amplitude-magnitude determinations, only the energy released relative to other events can be estimated; the magnitude listed in Tables B1 and B2 (Appendix B) should not be compared with the standard Richter magnitude scale.

A magnitude scale relating signal duration to magnitudes is provided in the program HYPO71 (Lee and Lahr, 1972); however, magnitudes calculated with the program gave values which seemed high. Furthermore, Lee and Lahr define signal duration to extend from the P onset to a point within the coda where a trace deflection of 1 cm is measurable on a Develocorder screen. Signal durations measured in this investigation were defined to be the time interval from the P onset until signals were indistinguishable from background noise levels. The heuristic equation used in this investigation for relative magnitudes was:

$$M_r = -2.0 + 2.0 \log_{10}(\tau) + 0.0035(\Delta),$$

where M_r, τ, and Δ are, respectively, relative magnitude, signal duration, and epicenter distance. Leading coefficients are Langenkamp's (Langenkamp and Combs, 1974), and the distance correction is from Lee and Lahr (1972).

Relative magnitudes for local events are included in Tables B1 and B2. Of particular interest are magnitude relationships for the three microearthquake clusters, Denio, Craine Creek, and Thousand Creek. Plots of relative magnitude versus the number of events with magnitude, M_r or greater, are given for the Denio and Thousand Creek clusters in Figure 21; Craine Creek events are not included because the distance, 38.5 km, is too great to derive meaningful recurrence relationships from six events with magnitudes of ∿1.0.

Figure 21 indicates slopes, or 'b' values, are nearly identical for Denio and Thousand Creek clusters. Combining data from the two clusters, b = 1.5. The 1.5 b value seems high when compared to Richter (1958);

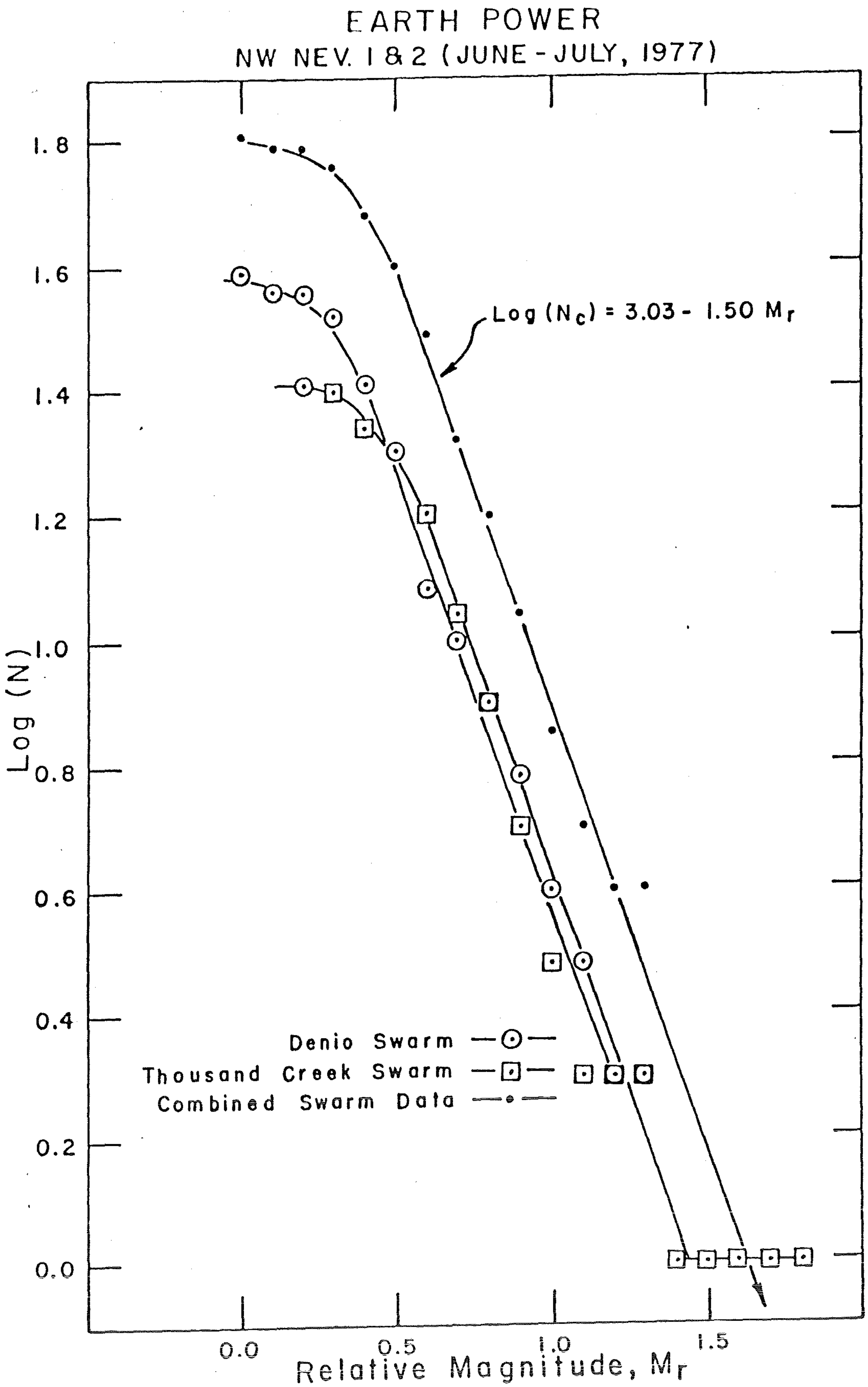


FIGURE 21. Frequency of occurrence, N, for Denio and Thousand Creek microearthquakes with magnitudes greater than or equal to M_r.

he indicates b values range from 0.7-1.5 where larger values pertain to larger earthquakes. Because the precise relationship is not known between Richter's magnitude scale and the relative magnitude scale used, the b value calculated for combined data is probably in error. Furthermore, Figure 21 indicates sampling is incomplete for events with relative magnitudes smaller than 0.4.

Figures 22 and 23 give detailed histories of the Denio and Thousand Creek events. Events tend to recur singly or in clusters of a few events. Larger events are not necessarily preceeded or followed by smaller events, and small events may occur singly. Temporal histories for Craine Creek events may be deduced from Figures 14 and 15; although histories for Craine Creek events with relative magnitudes less than 0.9 are not known, they also reoccurred as isolated events or in pairs. On a larger time scale, temporal clustering of events is evident because events from Denio and Craine Creek clusters were not observed during NW NEV 2 investigations; likewise, the NW NEV 1 array did not detect Thousand Creek events.

Recognizing shortcomings in the relative magnitude scale, some indication of the energy released per event can be obtained from Richter's magnitude-energy relationship,

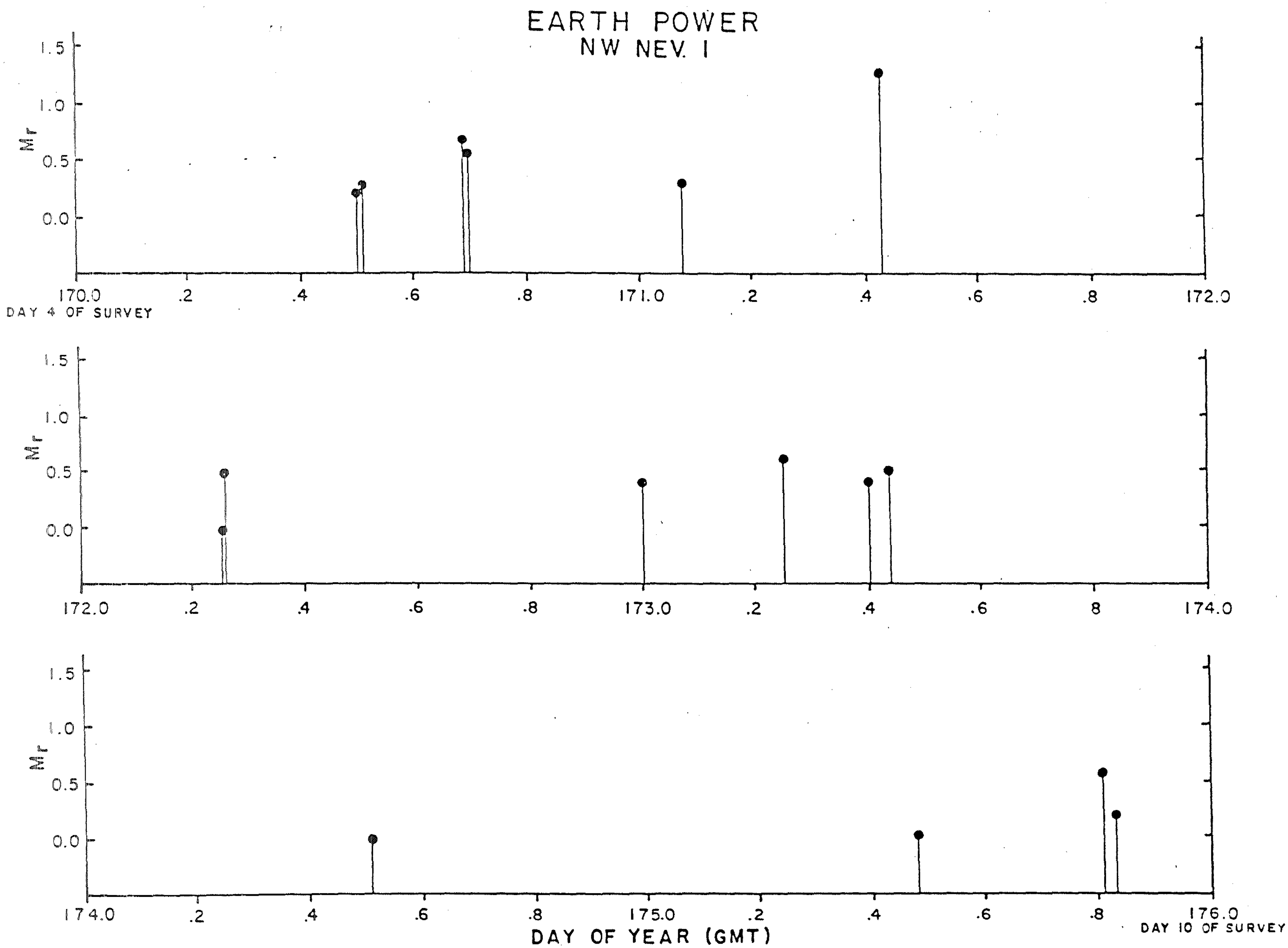
$$\log E_r = 11.8 + 1.5\ M_r.$$

Because M_r is substituted for M, the energy, E_r is defined in relative units rather than ergs as Richter's precise relationship gives.

Table 4 summarizes estimates of the total energy released from each of the three clusters and includes energy estimates per recording day. Had Craine Creek events been nearer the array, the energy released per day would probably have been equal to that at Denio, $\sim 2 \times 10^{13}$ energy units per day. The energy calculated for Thousand Creek includes an anomalous $M_r = 1.8$ event (Figure 23); excluding this event from Thousand Creek energy estimates per day, this cluster would also have released $\sim 2 \times 10^{13}$ energy units per day. The Thousand Creek event existed, and tape recording ceased when Denio events were still occurring, Figure 22. Hence, a more reasonable assumption is that energy released for each cluster was $\sim 5 \times 10^{13}$ energy units per recording day.

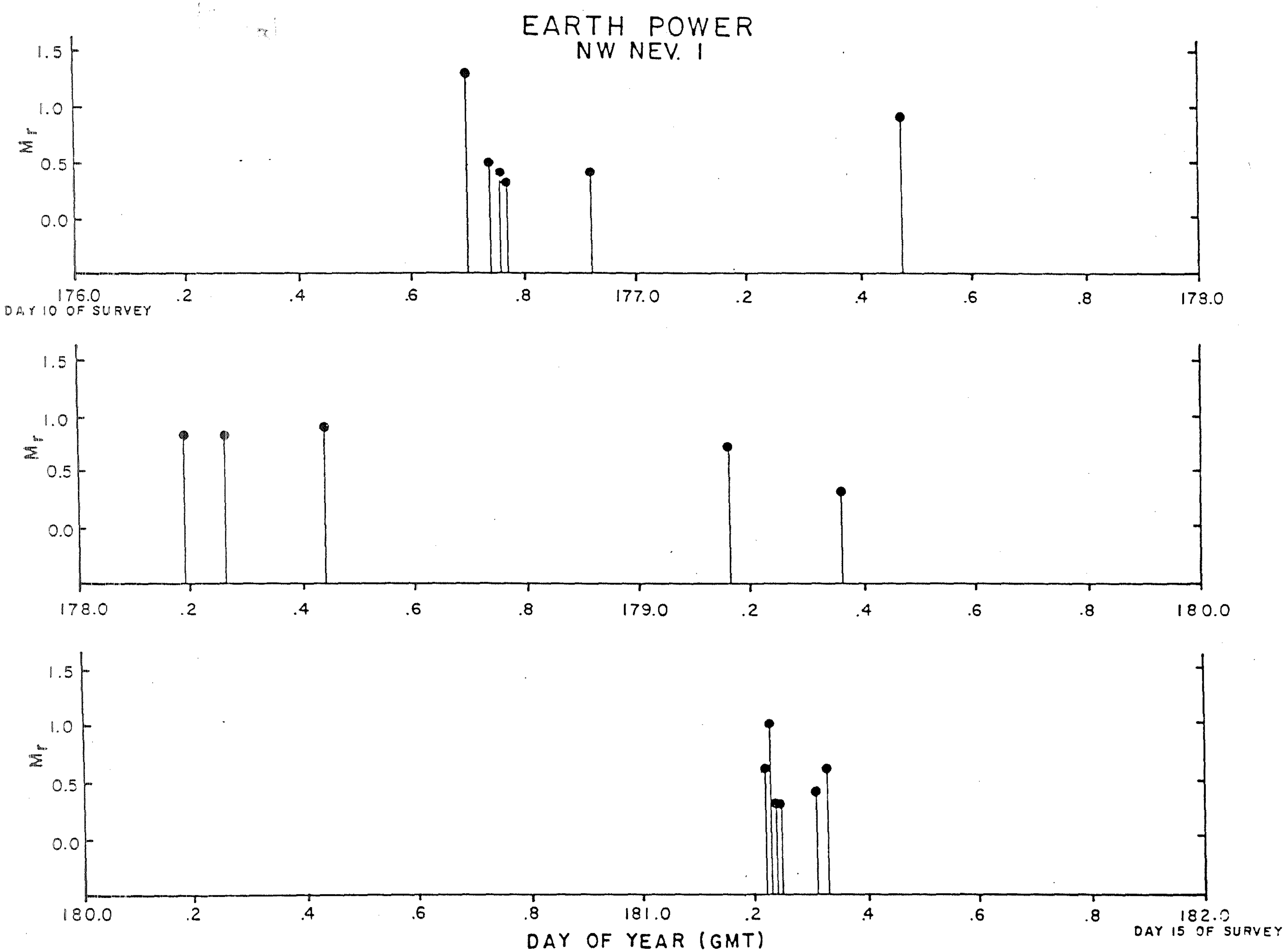
TABLE 4
ESTIMATES FOR THE TOTAL ENERGY RELEASED FROM
THREE N. W. NEVADA CLUSTER AREAS LISTED IN TABLE 1

Cluster	No. of Events Per Cluster	No. Of Recording Days	Total Energy Released, Energy Units	Energy Released Per Day, Energy Units/Day
Denio	39	15	3.0×10^{14}	2.0×10^{13}
Craine Creek	6	15	1.5×10^{14}	1.0×10^{13}
Thousand Creek	26	11	5.2×10^{14}	4.7×10^{13}



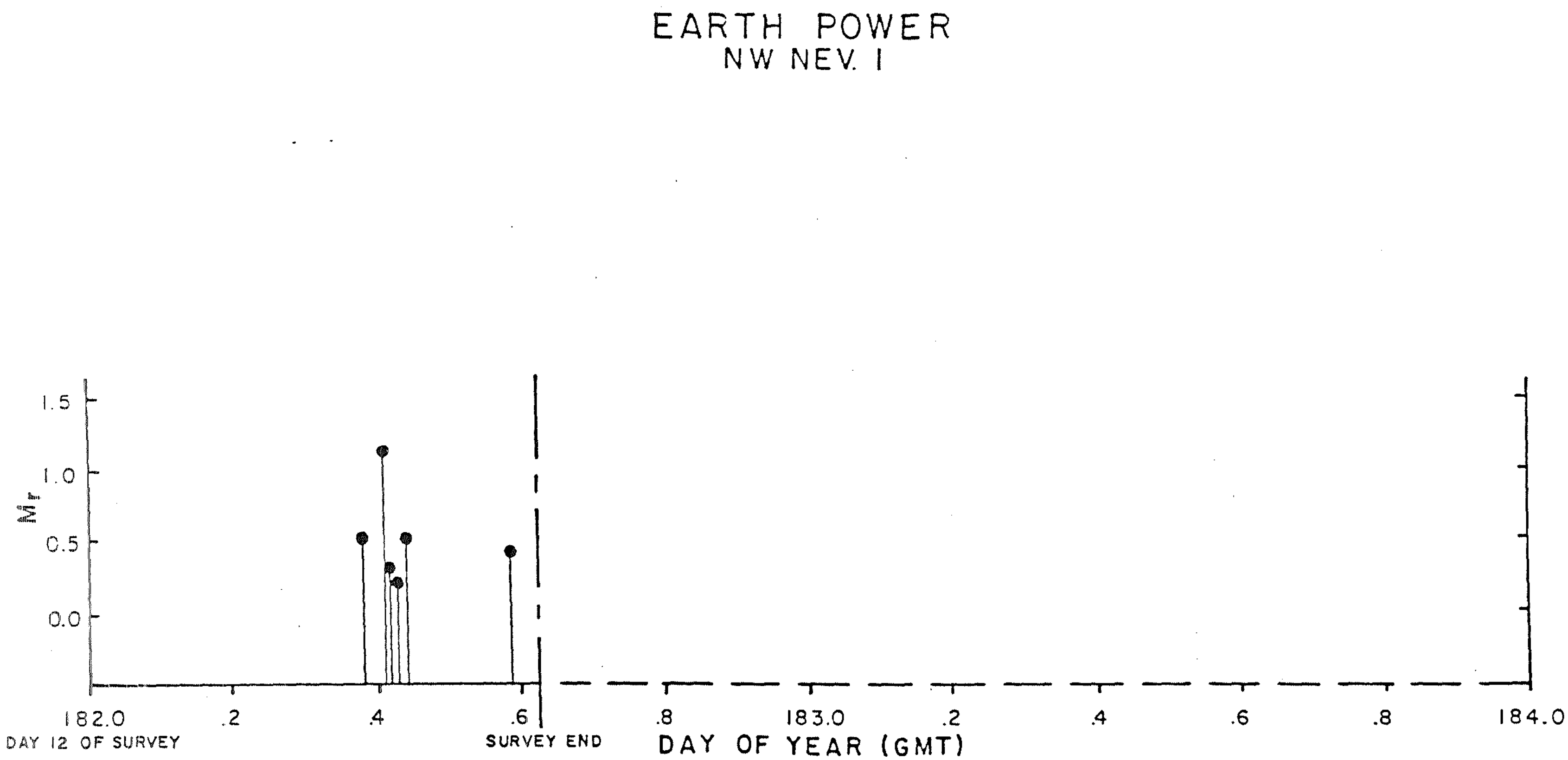
TEMPORAL HISTORY OF DETECTABLE DENIO EVENTS

FIGURE 22



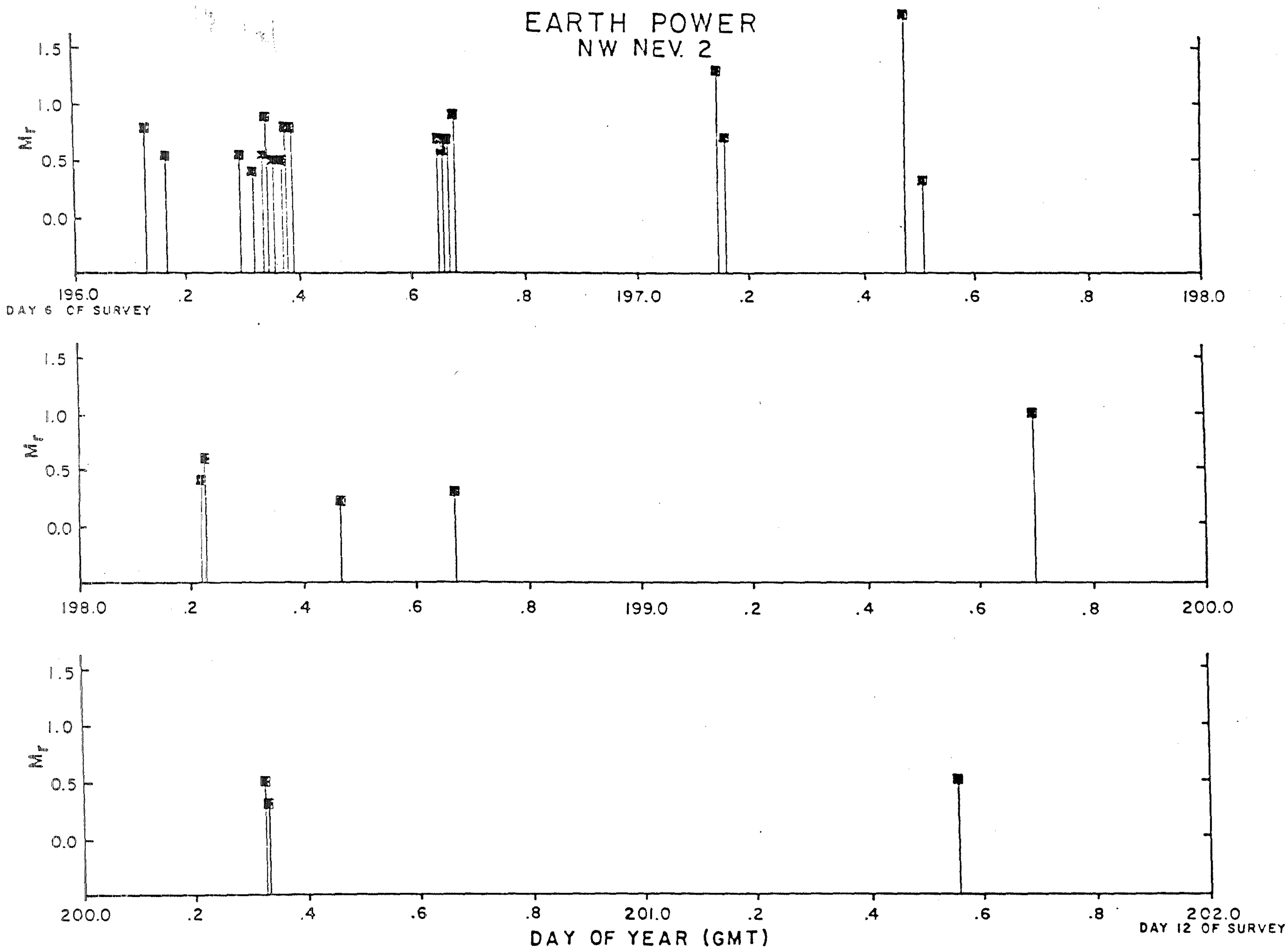
TEMPORAL HISTORY OF DETECTABLE DENIO EVENTS (Continued)

FIGURE 22 (Continued)



TEMPORAL HISTORY OF DETECTABLE DENIO EVENTS (Continued)

FIGURE 22 (Continued)



TEMPORAL HISTORY OF DETECTABLE THOUSAND CREEK EVENTS

FIGURE 23

FAULT PLANE SOLUTIONS WITH EMPHASIS ON THE DENIO SWARM

First motion plots for 27 well-located events from the Denio swarm are given in Figure 24. First motions are compatible with a fault plane which is typical of the Basin and Range: parallel to the linear mountain front and steeply dipping. The upthrown block west of the fault, the Pueblo Mountains, consists of Tertiary volcanics dipping 45° towards the west. First motions of the Denio cluster indicate compressional or upward motion on the west side of the fault.

A significant component of strike-slip motion is permitted, but is unlikely in this tectonic setting. The only known faults in the Basin and Range with significant strike-slip motion have right-lateral components trending about N. 30 W., and those with left-lateral components trend about N. 70 E.; none would be expected on a trend of N. 30°-33° E. in this region.

Selected solutions in Figure 24 suggest strike could trend N. 33° E. and have a reversed 75° westerly dip component. Another solution is to consider a vertical fault plane at 20° azimuth; this is probably a more reasonable solution in this area of WNW extension.

Craine Creek events were typically emergent but seemed to have upward first motion. However, the distance, 38.5 km from the NW NEV 1 array, is too great to resolve a reasonable focal mechanism. Thousand Creek events also had upward first motions (Figure 4). This could mean that the aforementioned Pueblo Mountain block moved upward relative to the western Railroad Point ridge. Alternatively, left-lateral, strike-slip motion could have occurred along the Thousand Creek lineament separating Pueblo Mountain block and Railroad Point ridge from McGee Mountain; this later solution cannot be excluded in view of the local topography.

CONCLUSIONS: RELEVANCE OF N. W. NEVADA SEISMICITY TO GEOTHERMAL INVESTIGATIONS

Knapp and Knight (1977) have shown that in regions with geothermal gradients greater than 10°C/km, heat generated by a hot pluton may induce detectable microearthquake swarms. With sufficient temperature increases, thermal expansion of the pore fluid will reduce effective pressures at the pore mineral interfaces and fracture rocks. Estimates of the energy released during fracture suggest that a magnitude 0 earthquake will occur if all pores fracture simultaneously in one cubic meter of rock with 1% porosity. A magnitude 3.6 earthquake results from simultaneous fracture of pores in $10^6 m^3$ (diameter $\sim$ 0.27 km) of the same rock. Greater porosity will increase the energy released in the same volume of rock. Open joints, however, will limit the volume of rock involved in a single fracture event, and thus restrict earthquake magnitudes.

This theory offers a plausible explanation for the swarms of microearthquakes detected in many Known Geothermal Resource Areas. It also suggests a reason for the lack of activity on other areas, especially those in the northwestern U. S. flood basalt provinces. Vertical cooling joints are common features of basalt flows; these open fractures may persist at depth where they are approximately normal to the lithostatic load.

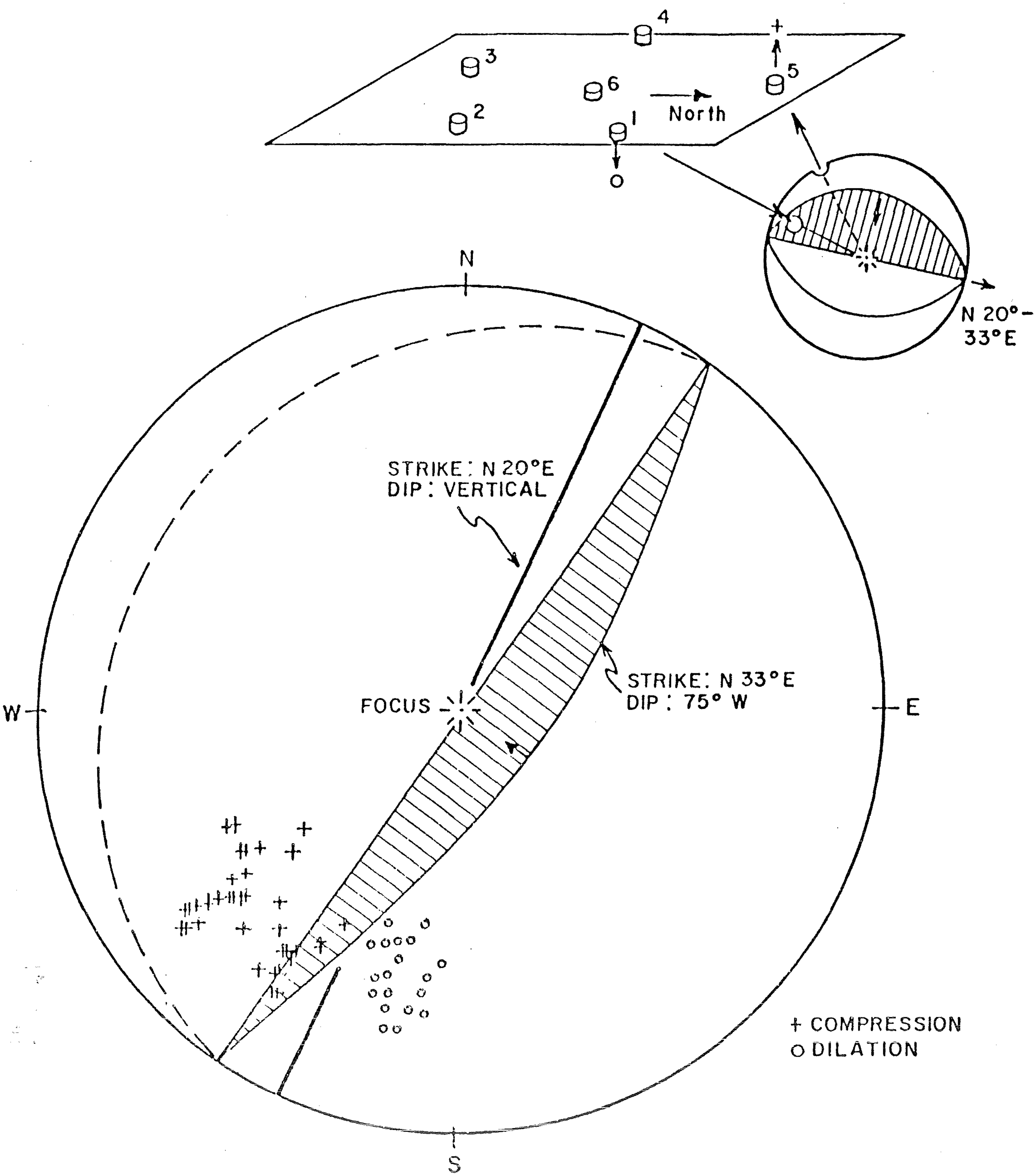


FIGURE 24. Selected fault plane solutions for the Denio cluster plotted on the upper portion of a unit sphere surrounding foci. Note how seismometer deflections in Figure 2 also suggest this solution.

Although joints may provide necessary fracture permeability for a geothermal reservoir, they limit the total volume of rock involved in a single fracture event. The magnitude of the induced earthquakes may thus be below the detection limit.

Microearthquake swarms detected by Senturion in geothermal areas throughout western U. S. commonly are restricted to very small source regions. The records of cluster events bear distinctive signatures; variations in stepout times are no greater than normal timing errors. These localized clusters generally occur along faults, and commonly near an intersecting cross-fault. Swarms may result from a combination of normal tectonic stresses along a major fault, fluids saturating the rocks, and high heat flows. Combined tectonic and thermal stress are relieved by point source microearthquake swarms where high pore pressures could prohibit the build-up of stresses for larger earthquakes.

Events from each of the Denio, Craine Creek, and Thousand Creek clusters are typical in this respect. Most epicenters fall within small circles with diameters of ∿2.5 km; depths of Denio events averaged 6.4 ± 0.6 km, and Thousand Creek events had nearly identical apparent velocities of 8.02 ± 0.14 km/sec indicating common focal depths. In view of the manner by which point source events may be overlaid and compared, the relatively small scatter in event positions can be attributed to small timing errors. Compared to other Nevada areas, few large events with magnitudes greater than 2 are known to occur in this northwestern area of Nevada (Priestley, 1974; Ryall, 1977).

Apparent velocity vectors were used to deduce N. W. Nevada media velocities and crustal models, to calibrate the NW NEV 2 array, and to determine location accuracies for both arrays; the vectors were essential for locating the Craine Creek and Thousand Creek clusters. Apparent velocity measurements indicated media velocities, Table 2, were typically those which are observed in western U. S., and the 6.4 km/sec granitic layer was easily recognized. Compared to The Geysers geothermal area, it could not be determined whether a shallow 4.3 km/sec overlaid the 5.6 km/sec upper layer observed during these investigations. Events were either too distant and critically refracted or local events were too deep (6-7.5 km) to resolve the near-surface velocity.

Vp/Vs ratios from combined Denio and Thousand Creek cluster data gave a Poisson's ratio of 0.22 ± .02. These clusters were at similar distances (10-11 km) from the measuring arrays and the measured ratio was probably affected by upper layer velocities. If the deeper granitic layer has a value of 0.25, then material near the surface has contaminated Vp/Vs measurements from events which are near the array. In fact, near-surface material would have to have a value less than 0.22; surface materials typically have values of ∿0.3. If the Vp/Vs measurements are correct, then the observed ratios suggest an anomalous, near-surface layer with a lower Poisson's ratio than is anticipated. This is encouraging news; according to Combs (1974), the low value for Poisson's ratio indicates that the shallow material is either deficient in liquid water saturation or that voids could be filled with steam. If this is the case with the N. W. Nevada area, a shallow, anomalous low-P wave velocity layer is suspected, and compares with that measured by Senturion at The Geysers; it would explain difficulties in assigning precise time corrections at selected stations.

Most N. W. Nevada microearthquakes recurred in small temporal clusters or as isolated events and from the same areas. Local event relative magnitudes ranged from -0.4 for a single event 7 km south of the NW NEV 1 array center, to M_r = 1.8 for a Thousand Creek event. A recurrence-magnitude, b value of 1.5 was obtained from Denio and Thousand Creek events; the value may be incorrect because a precise relationship between M_r and Richter's M was not known.

A fault plane solution for Denio events indicates normal faulting in that area; a solution for the Thousand Creek cluster was somewhat indeterminate but indicated either normal, or possibly left-lateral movement. The latter cluster occurred at a place where a cross-fault defined by the Thousand Creek Valley seems to intersect a north-trending fault along the eastern edge of Railroad Point ridge.

Local microseismicity, the anomalous Vp/Vs ratios, and the numerous hot springs indicate that the N. W. Nevada area should have good geothermal potential. Continued longer-term microearthquake investigations in the area should delineate new geothermal targets and provide additional information about the shallow layer velocities.

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APPENDIX A

Tables A1 and A2 list station coordinates for the respective NW NEV 1 and 2 surveys. The NW NEV 2 array was centered 16 km southwest from the first array. On July 14, 1977, Station #1 of the NW NEV 2 array was moved 0.24 km northeast of the original location. The first station location, Table A2a, is required for the first nine events listed in Tables B2 and B4; the remaining NW NEV 2 events require coordinates listed in Table A2b.

TABLE A1. NW NEV 1 Array Coordinates (July 16 through July 30, 1977).

PROJECT: NW NEV 1

STA	X KFT	Y KFT	Z KFT	DELZ KFT	AZIMUTH DEG	RAD MILES	LATITUDE DEG MIN	LONGITUDE DEG MIN	ELEV KM	DELZ KM
1	187.859	138.544	4.210	-.355	62.22	2.839	41 56.27	118 40.84	1.283	-.111
2	185.011	122.176	5.120	.545	129.42	2.798	41 53.61	118 41.25	1.561	.166
3	167.584	117.846	4.240	-.335	207.09	2.917	41 52.91	118 45.27	1.292	-.102
4	158.714	134.003	4.320	-.255	278.76	3.044	41 55.54	118 47.20	1.317	-.078
5	172.653	145.197	5.220	.645	351.89	2.609	41 57.36	118 44.16	1.591	.197
6*	174.765	131.574	4.340	-.235	83.99	.032*	41 55.14	118 43.70	1.323	-.072
AVG	174.593	131.557	4.575	.464		2.841*	41 55.14	118 43.74	1.394	.142

STATION NO. 6 EXCLUDED FROM AVERAGE RADIUS CALCULATIONS

ARRAY TILT: .8 DEG (422 FEET / 5.68 MILES) AT 227 DEG AZIMUTH

PROJECT: NW NEV 1

STA	X KM	Y KM	Z METER	DELZ METER	AZIMUTH DEG	RAD KM	LATITUDE DEG MIN	LONGITUDE DEG MIN	ELEV KM	DELZ KM
1	57.259	42.228	1283	-110	62.22	4.569	41 56.27	118 40.84	1.283	-.111
2	56.698	37.239	1560	166	129.42	4.503	41 53.61	118 41.25	1.561	.166
3	51.080	35.920	1292	-101	207.09	4.694	41 52.91	118 45.27	1.292	-.102
4	48.376	40.844	1316	-77	278.76	4.899	41 55.54	118 47.20	1.317	-.078
5	52.625	44.256	1591	197	351.89	4.200	41 57.36	118 44.16	1.591	.197
6*	53.268	40.104	1322	-71	83.99	.051*	41 55.14	118 43.70	1.323	-.072
AVG	53.217	40.099	1394	142		4.573*	41 55.14	118 43.74	1.394	.142

STATION NO. 6 EXCLUDED FROM AVERAGE RADIUS CALCULATIONS

ARRAY TILT: .8 DEG (129 METERS / 9.15 KM) AT 227 DEG AZIMUTH

TABLE A2a. NW NEV 2 Array Coordinates (June 9-June 13, 1977).

PROJECT: NW NEV 2A

STA	X KFT	Y KFT	Z KFT	DELZ KFT	AZIMUTH DEG	RAD MILES	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	ELEV KM	DELZ KM
1	133.117	102.270	4.280	-.433	44.25	2.876	41	50.37	118	48.42	1.305	-.138
2	154.278	83.526	4.370	-.363	123.79	2.679	41	47.33	118	48.17	1.332	-.111
3	141.290	76.715	4.470	-.263	184.80	2.790	41	46.22	118	51.00	1.362	-.080
4	129.193	68.754	6.120	1.387	258.79	2.572	41	48.18	118	53.64	1.865	.423
5	133.904	106.494	4.580	-.153	336.34	3.123	41	51.06	118	52.18	1.396	-.047
6*	141.342	90.602	4.580	-.153	236.11	.269*	41	48.48	118	50.99	1.396	-.047
AVG	142.522	91.394	4.733	.689		2.808*	41	48.61	118	50.73	1.443	.210

STATION NO. 6 EXCLUDED FROM AVERAGE RADIUS CALCULATIONS

ARRAY TILT: 3.2 DEG (1657 FEET / 5.62 MILES) AT 81 DEG AZIMUTH

PROJECT: NW NEV 2A

STA	X KM	Y KM	Z METER	DELZ METER	AZIMUTH DEG	RAD KM	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	ELEV KM	DELZ KM
1	46.570	31.172	1304	-137	44.25	4.628	41	50.37	118	48.42	1.305	-.138
2	47.024	25.459	1331	-110	123.79	4.312	41	47.33	118	48.17	1.332	-.111
3	43.063	23.383	1362	-79	184.80	4.490	41	46.22	118	51.00	1.362	-.080
4	39.380	27.052	1865	423	258.79	4.140	41	48.18	118	53.64	1.865	.423
5	41.424	32.459	1395	-46	336.34	5.025	41	51.06	118	52.18	1.396	-.047
6*	43.081	27.615	1395	-46	236.11	.433*	41	48.48	118	50.99	1.396	-.047
AVG	43.441	27.857	1442	210		4.519*	41	48.61	118	50.73	1.443	.210

STATION NO. 6 EXCLUDED FROM AVERAGE RADIUS CALCULATIONS

ARRAY TILT: 3.2 DEG (505 METERS / 9.04 KM) AT 81 DEG AZIMUTH

TABLE A2b. NW NEV 2 Array Coordinates (July 14 through July 20, 1977).

PROJECT: NW NEV 2B

STA	X KFT	Y KFT	Z KFT	DELZ KFT	AZIMUTH DEG	RAD MILES	LATITUDE DEG MIN	LONGITUDE DEG MIN	ELEV KM	DELZ KM
1	153.645	102.746	4.280	-.453	44.39	2.988	41 50.45	118 48.31	1.305	-.138
2	154.273	83.526	4.370	-.363	124.25	2.674	41 47.33	118 48.17	1.332	-.111
3	141.290	76.715	4.470	-.263	185.11	2.806	41 46.22	118 51.00	1.362	-.080
4	129.193	88.754	6.120	1.387	258.54	2.592	41 48.18	118 53.64	1.865	.423
5	135.904	106.494	4.580	-.153	333.94	3.116	41 51.06	118 52.18	1.396	-.047
6*	141.342	90.602	4.580	-.153	233.49	.291*	41 48.48	118 50.99	1.396	-.047
AVG	142.610	91.473	4.733	.689		2.835*	41 48.62	118 50.71	1.443	.210

STATION NO. 6 EXCLUDED FROM AVERAGE RADIUS CALCULATIONS

ARRAY TILT: 3.1 DEG (1640 FEET / 5.67 MILES) AT 82 DEG AZIMUTH

PROJECT: NW NEV 2B

STA	X KM	Y KM	Z METER	DELZ METER	AZIMUTH DEG	RAD KM	LATITUDE DEG MIN	LONGITUDE DEG MIN	ELEV KM	DELZ KM
1	46.831	31.317	1304	-137	44.39	4.808	41 50.45	118 48.31	1.305	-.138
2	47.024	25.459	1331	-110	124.25	4.303	41 47.33	118 48.17	1.332	-.111
3	43.065	23.383	1362	-79	185.11	4.516	41 46.22	118 51.00	1.362	-.080
4	39.380	27.052	1865	423	258.54	4.171	41 48.18	118 53.64	1.865	.423
5	41.424	32.459	1395	-46	333.94	5.014	41 51.06	118 52.18	1.396	-.047
6*	43.081	27.615	1395	-46	233.49	.469*	41 48.48	118 50.99	1.396	-.047
AVG	43.467	27.881	1442	210		4.562*	41 48.62	118 50.71	1.443	.210

STATION NO. 6 EXCLUDED FROM AVERAGE RADIUS CALCULATIONS

ARRAY TILT: 3.1 DEG (500 METERS / 9.12 KM) AT 82 DEG AZIMUTH

APPENDIX B

Tables B1 and B2 give locations for the events detected during the respective NW NEV 1 and 2 surveys. Also listed are the magnitudes for local events with S-P time intervals less than 5 seconds. Tables B3 and B4 give apparent velocity vector results for the corresponding events in Tables B1 and B2. Location assignments given in B1 and B2 take precedence over those listed in B3 and B4.

NW NEV 1 locations were calculated without station correction times; NW NEV 2 vector results were calculated with reduced weighting on Station #1 (¼ the normal value) and include station elevation corrections. NW NEV 2 corrections times for Stations 1-6 were, respectively: 0.000, -0.010, -0.020, -0.030, and -0.030 seconds.

TABLE B1. NW NEV 1 Seismicity Locations and Relative Magnitudes for Local Events

ARRAY CENTER: LATITUDE 41 55.14 LONGITUDE 118 43.74

EVENT	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	DEPTH KM	DIRECTION DEG	DISTANCE KM	DISTANCE MILE	RELATIVE MAGNITUDE	COMMENTS
1	40	59.17	115	37.73	?	111.8	279.0	174.4	?	2,7
2	40	30.87	116	42.81	?	132.7	230.0	143.8	?	2,7
3		?		?	?	223.3	?	?	?	1
4		?		?	?	324.4	?	?	?	1
5		?		?	?	?	?	?	?	6
6	39	59.57	118	22.32	?	172.0	216.0	135.0	?	2,7
7		?		?	?	229.3	?	?	?	2,7,8
8		?		?	?	202.3	?	?	?	1
9	40	10.06	115	7.57	?	122.7	360.0	225.0	?	2,7
10		?		?	?	200.1	?	?	?	1
11		?		?	?	127.7	?	?	?	1
12	41	31.12	113	28.12	?	95.8	440.0	275.0	?	2
13	41	35.55	118	53.06	?	199.6	38.5	24.1	0.9	3,6,7
14		?		?	?	316.6	?	?	?	1
15	42	.22	118	39.62	?	31.2	11.0	6.9	0.2	4,7
16	42	.29	118	39.77	?	29.9	11.0	6.9	0.3	4,7
17	42	.27	118	39.72	?	30.3	11.0	6.9	0.7	4,7
18	42	.17	118	39.51	?	32.1	11.0	6.9	0.6	4
19	42	.05	118	40.13	7.6	28.6	10.3	6.5	0.3	4
20	41	14.23	115	5.25	?	104.0	313.0	195.6	?	2
21	42	.13	118	39.42	?	32.9	11.0	6.9	1.3	4
22		?		?	?	?	?	?	?	2,5,8
23	41	57.39	118	47.81	?	306.6	7.0	4.4	-.0	3,7
24	41	59.98	118	39.62	?	32.4	10.6	6.6	0.5	4
25		?		?	?	203.4	?	?	?	1

COMMENTS:

1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B1 (Continued). NW NEV 1 Seismicity Locations

EVENT	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	DEPTH KM	DIRECTION DEG	DISTANCE KM	DISTANCE MILE	RELATIVE MAGNITUDE	COMMENTS
26	?		?		?	204.8	?	?	?	1
27	41	59.49	118	39.25	6.5	37.6	10.2	6.4	0.4	4,7
28	41	59.91	118	39.36	7.0	34.4	10.7	6.7	0.6	4
29	?		?		?	326.8	?	?	?	1
30	?		?		?	334.3	?	?	?	1
31	42	.39	118	40.00	?	28.0	11.0	6.9	0.4	4,7
32	42	.15	118	39.45	5.0	32.6	11.0	6.9	0.5	4
33	?		?		?	208.4	?	?	?	1
34	41	51.31	118	43.42	?	176.4	7.1	4.4	-.4	2,7
35	43	39.34	118	39.79	?	1.6	193.0	120.6	?	2
36	41	55.70	118	48.52	12.5	293.6	7.2	4.5	0.4	3
37	?		?		?	?	11.0	6.9	-.0	4,5
38	40	17.81	115	42.67	?	125.4	311.0	194.4	?	2
39	?		?		?	195.4	?	?	?	1
40	41	35.02	118	52.11	?	197.3	39.0	24.4	1.1	3,6
41	41	35.09	118	52.39	?	197.9	39.0	24.4	1.1	3,6
42	41	59.82	118	39.75	4.9	32.5	10.3	6.4	0.0	4
43	40	39.51	116	32.13	?	127.3	231.0	144.4	2.6	2
44	42	.30	118	40.70	6.5	23.7	10.4	6.5	0.6	4
45	41	59.60	118	38.48	?	41.4	11.0	6.9	0.2	4
46	?		?		?	109.3	?	?	?	2,8
47	41	35.32	118	52.14	?	197.6	38.5	24.1	1.1	3,6,7
48	41	34.97	118	51.87	?	196.8	39.0	24.4	1.2	3,6
49	42	.10	118	39.35	?	33.5	11.0	6.9	1.3	4
50	41	59.98	118	39.69	6.4	30.7	10.4	6.5	0.5	4

COMMENTS:

1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B1 (Continued). NW NEV 1 Seismicity Locations

EVENT	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	DEPTH KM	DIRECTION DEG	DISTANCE KM	DISTANCE MILE	RELATIVE MAGNITUDE	COMMENTS
51	42	1.17	118	37.85	6.7	36.1	13.8	8.6	0.4	4
52	42	.10	118	39.36	?	33.4	11.0	6.9	0.3	4,7
53	42	2.52	119	56.92	?	277.7	102.0	63.8	1.6	2
54	42	.14	118	39.42	5.0	32.8	11.0	6.9	0.4	4
55	41	35.71	118	52.57	?	198.8	38.0	23.8	0.9	3,6,7
56		?		?	?	166.8	?	?	?	1
57		?		?	?	101.4	?	?	?	1
58	41	59.96	118	39.27	6.3	34.0	10.8	6.8	0.9	4
59	41	44.55	118	49.18	?	201.0	21.0	13.1	1.0	3
60	41	58.30	119	4.29	?	281.6	29.0	18.1	1.1	3
61	42	.11	118	39.50	5.0	32.5	10.9	6.8	0.8	4
62	41	59.67	118	39.58	6.0	34.4	10.2	6.4	0.8	4
63	41	59.49	118	39.72	5.8	34.6	9.8	6.1	0.9	4
64		?		?	?	118.3	?	?	?	1
65		?		?	?	?	430.0	268.8	?	2,5
66	42	.18	118	39.29	6.4	33.4	11.2	7.0	0.7	4
67	42	.17	118	39.56	5.0	31.8	11.0	6.8	0.3	4
68	40	7.00	115	25.05	?	125.7	343.0	214.4	?	2
69		?		?	?	102.2	?	?	?	1
70		?		?	?	322.8	?	?	?	1
71	40	53.45	116	24.64	?	120.5	225.0	140.6	?	2
72	41	59.93	118	39.41	7.0	34.0	10.7	6.7	0.6	4
73	41	59.56	118	39.86	5.0	33.2	9.8	6.1	1.0	4
74	41	59.68	118	39.39	6.6	35.6	10.3	6.5	0.3	4
75	42	.04	118	39.32	5.0	34.0	10.9	6.8	0.3	4

COMMENTS:
1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B1 (Continued). NW NEV 1 Seismicity Locations

EVENT	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	DEPTH KM	DIRECTION DEG	DISTANCE KM	DISTANCE MILE	RELATIVE MAGNITUDE	COMMENTS
76	42	.06	118	39.51	5.0	32.7	10.8	6.8	0.4	4
77	41	59.74	118	39.46	6.4	34.8	10.4	6.5	0.6	4
78	41	47.26	118	38.98	?	155.7	16.0	10.0	0.7	3
79	41	59.77	118	39.49	6.1	34.4	10.4	6.5	0.5	4
80	41	58.93	118	40.30	5.0	34.1	8.5	5.3	1.1	4
81	42	.19	118	39.50	5.0	32.1	11.0	6.9	0.3	4
82	41	59.71	118	40.58	8.3	27.3	9.5	6.0	0.2	4
83	41	59.65	118	39.43	6.6	35.5	10.3	6.4	0.5	4
84	42	.18	118	39.47	5.0	32.3	11.0	6.9	0.4	4

COMMENTS:
1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B2. NW NEV 2 Seismicity Locations and Relative Magnitudes for Local Events

ARRAY CENTER: LATITUDE 41 48.62 LONGITUDE 118 50.71

EVENT	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	DEPTH KM	DIRECTION DEG	DISTANCE KM	DISTANCE MILE	RELATIVE MAGNITUDE	COMMENTS
1		?		?	?	209.2	?	?	?	1,5
2	41	59.48	118	33.27	?	50.2	31.4	19.6	1.3	3
3		?		?	?	290.8	?	?	?	1,5
4		?		?	?	242.8	?	?	?	1,5
5		?		?	?	239.6	?	?	?	1,5
6	41	35.44	120	10.02	?	257.5	112.7	70.4	?	2,9
7	41	33.07	118	28.77	?	133.4	41.9	26.2	0.9	2,9
8	41	33.60	119	47.60	?	250.6	83.7	52.3	1.4	2
9	41	52.86	119	48.59	?	275.6	80.5	50.3	1.4	2
10		?		?	?	303.8	?	?	?	1,5
11	41	53.86	118	50.89	?	358.5	9.7	6.1	0.8	3,4
12	41	54.03	118	51.62	?	352.8	10.1	6.3	0.6	3,4,9
13	41	45.86	118	43.76	?	117.9	10.9	6.8	0.5	3
14	41	53.74	118	51.09	?	356.8	9.5	5.9	0.6	3,4
15	41	53.64	118	50.70	?	.1	9.3	5.8	0.4	3,4
16	41	53.91	118	50.90	?	358.5	9.8	6.1	0.6	3,4
17	41	54.05	118	51.38	?	354.7	10.1	6.3	0.9	3,4
18	41	33.89	119	52.67	?	252.4	90.2	56.4	1.5	2
19	41	54.18	118	51.05	?	357.4	10.3	6.4	0.5	3,4
20	41	53.86	118	50.70	?	.1	9.7	6.1	0.5	3,4,9
21	41	54.07	118	51.12	?	356.8	10.1	6.3	0.8	3,4
22	41	54.06	118	51.28	?	355.5	10.1	6.3	0.8	3,4
23	41	53.91	118	51.03	?	357.0	9.8	6.1	0.7	3,4
24		?		?	?	?	10.1	6.3	?	3,4,5,9
25	41	54.07	118	51.14	?	356.6	10.1	6.3	0.6	3,4,9

COMMENTS:

1. TELESEISM, FREQUENCY @ 2 HZ
2. REGIONAL EVENT, S-P > 5 SEC
3. LOCAL EVENT, S-P < 5 SEC
4. THOUSAND CREEK EVENT, DEPTH FIXED AT 7.5 KM
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL NOISE (SONIC)
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME
9. EMERGENT OR NOISY ARRIVALS

TABLE B2 (Continued). NW NEV 2 Seismicity Locations

EVENT	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	DEPTH KM	DIRECTION DEG	DISTANCE KM	DISTANCE MILE	RELATIVE MAGNITUDE	COMMENTS
26	41	54.00	118	51.42	?	354.4	10.0	6.3	0.7	3,4
27	41	54.00	118	51.29	?	355.4	10.0	6.3	0.9	3,4
28	40	35.59	117	11.97	?	134.4	193.2	120.8	?	2,5
29	41	54.35	118	50.64	?	.5	10.6	6.6	1.3	3,4
30	41	54.25	118	49.76	?	7.2	10.5	6.6	0.7	3,4,9
31	41	54.33	118	51.36	?	355.1	10.6	6.6	1.8	3,4
32	41	54.67	118	51.78	?	352.5	11.3	7.1	0.3	3,4
33		?		?	?	274.8	?	?	?	2,5
34	41	54.29	118	50.74	?	359.8	10.5	6.6	0.4	3,4,9
35	41	54.02	118	50.86	?	358.6	10.0	6.3	0.6	3,4,9
36	41	50.46	119	49.76	?	247.7	88.6	55.4	1.4	2,9
37		?		?	?	105.5	?	?	?	6
38	41	53.59	118	50.73	?	359.8	9.2	5.8	0.2	3,4,9
39		?		?	?	224.7	?	?	?	1,5
40	42	5.49	119	57.07	?	288.7	97.4	60.9	1.5	2,9
41	41	54.07	118	51.16	?	356.5	10.1	6.3	0.3	3,4,9
42	40	39.34	118	42.04	?	174.6	128.8	80.5	1.6	2,9
43	42	8.15	119	3.59	?	333.8	40.3	25.2	1.6	2
44	41	53.85	118	51.16	?	356.3	9.7	6.1	1.0	3,4,9
45		?		?	?	266.8	?	?	?	1,5,9
46	41	.75	117	7.36	?	121.6	169.1	105.7	2.6	2
47	40	57.27	117	10.39	?	124.2	169.1	105.7	?	2,5
48	41	53.85	118	51.16	?	356.3	9.7	6.1	0.5	3,4,9
49	41	54.06	118	51.22	?	356.0	10.1	6.3	0.3	3,4,9
50		?		?	?	?	58.0	36.3	1.0	2,9

COMMENTS:

1. TELESEISM, FREQUENCY @ 2 HZ
2. REGIONAL EVENT, S-P > 5 SEC
3. LOCAL EVENT, S-P < 5 SEC
4. THOUSAND CREEK EVENT, DEPTH FIXED AT 7.5 KM
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL NOISE (SONIC)
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME
9. EMERGENT OR NOISY ARRIVALS

TABLE B2 (Continued). NW NEV 2 Seismicity Locations

EVENT	LATITUDE DEG	LATITUDE MIN	LONGITUDE DEG	LONGITUDE MIN	DEPTH KM	DIRECTION DEG	DISTANCE KM	DISTANCE MILE	RELATIVE MAGNITUDE	COMMENTS
51	41	11.83	118	36.77	?	164.1	70.8	44.3	1.5	2,9
52	40	30.67	117	3.91	?	134.0	207.7	129.8	?	2,5
53	41	59.55	117	40.05	?	78.3	99.8	62.4	1.3	2,9
54	41	54.56	118	40.69	?	51.6	17.7	11.1	0.7	3,7
55	?		?		?	293.5	?	?	?	1,5
56	39	58.35	116	58.81	?	142.4	257.6	161.0	?	2,5,9
57	41	53.91	118	50.93	?	358.2	9.8	6.1	0.5	3,4,9
58	?		?		?	296.3	?	?	?	1,5
59	40	36.80	116	26.47	?	123.4	241.5	150.9	?	2,5,9
60	40	42.79	116	21.43	?	120.3	241.5	150.9	?	2,5
61	41	39.55	118	56.31	?	204.8	18.5	11.6	0.7	3
62	?		?		?	202.8	?	?	?	1,5,9
63	?		?		?	307.4	?	?	?	1,5,9

COMMENTS:

1. TELESEISM, FREQUENCY ≤ 2 HZ
2. REGIONAL EVENT, S-P > 5 SEC
3. LOCAL EVENT, S-P < 5 SEC
4. THOUSAND CREEK EVENT, DEPTH FIXED AT 7.5 KM
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL NOISE (SONIC)
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME
9. EMERGENT OR NOISY ARRIVALS

TABLE B3. NW NEV 1 Apparent Velocity Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
1	167/19/ 2	111.8± 4.1	8.8± .6	29.0± 2.2	(4)	278	173	2,7
2	167/22/20	132.7± ?	6.2± ?	20.5± ?	(1)	230	143	2,7
3	168/ 2/40	223.3± 3.1	35.1± 1.8	115.1± 6.2	(15)	?	?	1
4	168/14/57	324.4± 1.3	45.3± 1.1	148.6± 3.7	(3)	?	?	1
5	168/19/23	?	?	?	(0)	?	?	6
6	168/22/25	172.0± 2.2	6.5± .3	21.5± 1.0	(4)	215	134	2,7
7	168/23/32	229.3± 2.3	6.5± .2	21.6± .8	(3)	?	?	2,7,8
8	169/ 2/ 1	202.3± 2.2	42.5± 2.1	139.4± 7.2	(3)	?	?	1
9	169/ 6/25	122.7± .5	8.1± .2	26.6± .7	(2)	360	224	2,7
10	169/10/15	200.1± 2.8	37.2± 1.8	122.0± 6.2	(15)	?	?	1
11	169/21/ 3	127.7± 1.6	11.6± .2	38.3± .9	(4)	?	?	1
12	170/ 6/41	95.8± 2.0	7.5± .2	24.8± .8	(15)	439	273	2
13	170/10/39	199.6± 4.1	6.6± .4	21.7± 1.4	(15)	38	24	3,6,7
14	170/11/57	316.6± 4.5	17.4± 1.0	57.1± 3.4	(7)	?	?	1
15	170/12/ 1	31.2± ?	5.8± ?	19.2± ?	(1)	11	7	4,7

COMMENTS:
1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B3 (Continued). NW NEV 1 Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
16	170/12/ 9	29.9± ?	5.9± ?	19.5± ?	(1)	11	7	4,7
17	170/16/46	30.3± ?	5.9± ?	19.6± ?	(1)	11	7	4,7
18	170/16/48	32.1± 9.3	6.1± .9	20.0± 3.0	(7)	11	7	4
19	171/ 1/49	24.0± 8.0	7.2± 1.0	23.8± 3.5	(3)	11	7	4
20	171/ 8/20	104.0± 2.3	6.9± .4	22.7± 1.4	(7)	313	195	2
21	171/10/22	32.9±11.6	6.6± 1.1	21.9± 3.9	(15)	11	7	4
22	172/ 2/44	?	?	?	(0)	?	?	2,5,8
23	172/ 6/ 5	306.6± ?	8.6± ?	28.2± ?	(1)	6	4	3,7
24	172/ 6/ 6	32.0± 5.5	5.9± .5	19.5± 1.8	(7)	11	7	4
25	172/ 8/50	203.4± 6.3	37.1± 6.5	121.9±21.5	(7)	?	?	1
26	172/ 9/ 9	204.8± 1.7	24.8± .8	81.5± 2.7	(4)	?	?	1
27	172/23/57	43.4±11.0	5.5± .1	18.3± .5	(2)	11	7	4,7
28	173/ 6/ 3	34.1±11.2	6.4± 1.0	21.1± 3.6	(15)	11	7	4
29	173/ 7/23	326.8± 3.4	28.3± 1.3	93.0± 4.4	(15)	?	?	1
30	173/ 8/59	334.3± .3	20.1± .1	66.0± .4	(7)	?	?	1

COMMENTS:
1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B3 (Continued). NW NEV 1 Vec or Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
31	173/ 9/37	28.0± ?	6.4± ?	21.0± ?	(1)	11	7	4,7
32	173/10/37	32.6± 9.4	6.1± .9	20.1± 3.0	(7)	11	7	4
33	173/12/20	208.4± 3.5	26.3± 1.5	86.4± 5.2	(15)	?	?	1
34	173/19/36	176.4± ?	7.5± ?	24.6± ?	(1)	6	4	2,7
35	174/ 0/ 4	1.6± 2.0	8.2± .5	27.1± 1.7	(7)	193	120	2
36	174/21/31	295.5±10.9	11.5± 1.6	37.8± 5.3	(15)	8	5	3
37	174/12/15	?	?	?	(0)	11	7	4,5
38	174/22/23	125.4± 3.1	8.1± .5	26.8± 1.8	(15)	310	193	2
39	175/ 0/42	195.4± 4.3	46.8± 2.5	153.5± 8.3	(7)	?	?	1
40	175/ 8/21	197.3± 4.4	6.1± .4	20.1± 1.6	(15)	38	24	3,6
41	175/11/17	197.9± 2.9	6.1± .3	20.2± 1.2	(15)	38	24	3,6
42	175/11/34	31.8±11.1	5.9± 1.0	19.5± 3.5	(3)	11	7	4
43	175/19/13	127.3± 3.3	7.4± .6	24.4± 2.1	(7)	231	144	2
44	175/19/27	19.5±17.5	7.1± 2.0	23.3± 6.7	(7)	11	7	4
45	175/19/51	41.4± 7.3	6.4± 1.1	21.2± 3.7	(4)	11	7	4

COMMENTS:
1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B3 (Continued). NW NEV 1 Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
46	176/ 1/25	109.3± 3.9	6.3± .3	20.9± 1.3	(12)	?	?	2,8
47	176/ 1/38	197.6± 2.7	6.2± .2	20.4± .9	(4)	38	24	3,6,7
48	176/ 1/54	196.8± 7.2	6.5± .5	21.4± 1.7	(7)	38	24	3,6
49	176/16/46	33.5±11.3	6.4± 1.1	21.2± 3.7	(15)	11	7	4
50	176/17/46	26.9± 8.8	6.8± 1.0	22.3± 3.5	(3)	11	7	4
51	176/18/24	34.4± 1.6	5.5± .2	18.2± .7	(4)	11	7	4
52	176/18/25	33.4± ?	5.3± ?	17.7± ?	(1)	11	7	4,7
53	176/20/37	277.7± 3.3	7.8± .3	25.9± 1.1	(15)	101	63	2
54	176/22/ 5	32.6± 9.7	6.0± .9	19.9± 3.1	(7)	11	7	4
55	177/ 5/ 1	198.8± 2.4	5.9± .1	19.6± .4	(4)	38	24	3,6,7
56	177/ 6/11	166.8± 3.5	48.3± 3.9	158.4±13.1	(7)	?	?	1
57	177/10/24	101.4± 2.2	11.0± .4	36.3± 1.5	(15)	?	?	1
58	177/11/18	34.1±11.8	6.5± 1.1	21.4± 3.9	(15)	11	7	4
59	177/14/ 4	201.1± 5.2	7.2± .4	23.9± 1.5	(7)	20	13	3
60	177/15/46	281.6± .3	7.9± .0	26.0± .1	(4)	28	18	3

COMMENTS:

1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B3 (Continued). NW NEV 1 Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
61	178/ 4/39	32.1± 9.8	6.0± .9	19.9± 3.2	(7)	11	7	4
62	178/ 6/11	33.9±11.5	6.4± 1.1	21.2± 3.7	(15)	11	7	4
63	178/10/39	33.9±11.4	6.4± 1.1	21.3± 3.7	(15)	11	7	4
64	178/19/ 7	118.3± 5.5	10.8± .7	35.6± 2.6	(15)	?	?	1
65	179/ 3/42	?	?	?	(0)	429	267	2,5
66	179/ 3/48	32.2±10.0	6.1± 1.0	20.0± 3.3	(7)	11	7	4
67	179/ 8/45	31.8± 9.6	6.1± .9	20.3± 3.1	(7)	11	7	4
68	179/23/ 8	125.7± 2.7	6.0± .2	19.9± .8	(4)	342	213	2
69	180/ 7/42	102.2± 3.7	53.0± 1.9	174.0± 6.5	(15)	?	?	1
70	180/ 8/54	322.8± 4.8	16.4± 1.6	54.0± 5.5	(15)	?	?	1
71	180/19/ 9	120.5± 4.3	6.8± .8	22.4± 2.7	(7)	225	140	2
72	181/ 5/17	33.5±12.3	6.4± 1.2	21.1± 4.1	(15)	11	7	4
73	181/ 5/34	32.2± 9.4	6.0± .9	19.9± 3.1	(7)	11	7	4
74	181/ 5/42	36.8±10.1	6.5± .9	21.5± 3.2	(15)	11	7	4
75	181/ 5/52	37.3±10.4	6.1± 1.4	20.3± 4.7	(3)	11	7	4

COMMENTS:
1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B3 (Continued). NW NEV 1 Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
76	181/ 7/30	35.7± 8.6	6.1± 1.0	20.2± 3.6	(3)	11	7	4
77	181/ 7/48	36.5±10.5	5.8± .8	19.2± 2.8	(7)	11	7	4
78	182/ 3/11	155.7± 6.5	6.4± .7	21.0± 2.5	(7)	16	10	3
79	182/ 9/13	33.9±11.3	6.4± 1.1	21.1± 3.7	(15)	11	7	4
80	182/ 9/57	34.0±11.5	6.4± 1.1	21.3± 3.7	(15)	11	7	4
81	182/10/ 1	31.9± 9.4	6.1± .9	20.0± 3.1	(7)	11	7	4
82	182/10/22	42.3±12.8	5.4± .1	17.9± .6	(2)	11	7	4
83	182/10/37	36.7± 9.2	6.5± .9	21.5± 3.0	(15)	11	7	4
84	182/14/14	32.0± 9.7	6.0± .9	19.8± 3.1	(7)	11	7	4

COMMENTS:

1. TELESEISM, FREQUENCY = 2 HZ
2. REGIONAL EVENT, S-P TIME > 5
3. LOCAL EVENT, S-P TIME < 5
4. DENIO SWARM EVENT
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL OR SYSTEM NOISE
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME

TABLE B4. NW NEV 2 Apparent Velocity Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
1	191/ 5/23	209.2±20.0	26.6± 8.2	87.5±27.2	(15)	?	?	1
2	191/22/38	50.2± .8	6.0± .1	19.7± .4	(15)	31	19	3
3	192/ 9/46	290.8±17.2	16.5± 5.6	54.4±18.5	(15)	?	?	1
4	193/ 1/44	242.8± 4.8	10.6± 1.7	35.0± 5.7	(15)	?	?	1
5	193/ 5/18	239.6± 1 5	8.7± .4	28.7± 1.4	(15)	?	?	1
6	193/ 6/49	257.5± 3.2	7.1± .5	23.5± 1.7	(15)	112	70	2,9
7	193/10/ 1	133.4± .2	5.1± .0	16.9± .1	(7)	41	26	2,9
8	194/10/10	250.6± 7.4	5.9± .9	19.6± 3.0	(7)	83	52	2
9	194/13/19	275.6± 2.7	5.6± .2	18.5± .8	(7)	80	50	2
10	196/ 2/26	303.8±25.9	33.2±12.9	109.0±42.6	(15)	?	?	1
11	196/ 3/12	358.5± 4.7	7.9± .5	26.1± 1.8	(15)	9	6	3,4
12	196/ 4/ 6	352.8± 6.4	8.2± .9	27.1± 3.1	(7)	10	6	3,4,9
13	196/ 7/ 6	117.9± 4.2	6.3± .4	20.9± 1.4	(15)	10	6	3
14	196/ 7/15	356.8± 7.2	7.8± .8	25.7± 2.7	(15)	9	6	3,4
15	196/ 7/44	.1± 5.1	7.9± .6	26.1± 2.0	(15)	9	6	3,4

COMMENTS:

1. TELESEISM, FREQUENCY @ 2 HZ
2. REGIONAL EVENT, S-P > 5 SEC
3. LOCAL EVENT, S-P < 5 SEC
4. THOUSAND CREEK EVENT, DEPTH FIXED AT 7.5 KM
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL NOISE (SONIC)
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME
9. EMERGENT OR NOISY ARRIVALS

TABLE B4 (Continued). NW NEV 2 Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
16	196/ 8/ 9	358.5± 7.1	8.3± .8	27.5± 2.9	(15)	9	6	3,4
17	196/ 8/27	354.7± 6.4	8.0± .7	26.3± 2.4	(15)	10	6	3,4
18	196/ 8/37	252.4± 3.1	5.6± .3	18.4± 1.3	(15)	90	56	2
19	196/ 8/42	357.4± 5.6	8.1± .6	26.6± 2.2	(15)	10	6	3,4
20	196/ 9/ 2	.1± 3.1	7.9± .3	26.0± 1.2	(15)	9	6	3,4,9
21	196/ 9/ 5	356.8± 3.5	8.2± .4	27.1± 1.4	(15)	10	6	3,4
22	196/ 9/25	355.5± 4.6	7.9± .5	26.2± 1.7	(15)	10	6	3,4
23	196/15/43	357.0± 5.3	7.8± .6	25.9± 2.0	(15)	9	6	3,4
24	196/15/45	?	?	?	(0)	9	6	3,4,5
25	196/15/57	356.6± 1.3	8.8± .2	28.9± .7	(2)	10	6	3,4,9
26	196/15/59	354.4± 5.3	7.9± .6	26.2± 2.0	(15)	9	6	3,4
27	196/16/18	355.4± 5.1	8.0± .5	26.3± 1.9	(15)	9	6	3,4
28	196/17/15	134.4± 2.3	6.4± .1	21.1± .6	(15)	193	120	2
29	197/ 3/40	.5± 5.6	7.9± .6	26.2± 2.2	(15)	11	7	3,4
30	197/ 3/55	7.2± 8.1	9.2± .7	30.2± 2.6	(7)	11	7	3,4,9

COMMENTS:
1. TELESEISM, FREQUENCY @ 2 HZ
2. REGIONAL EVENT, S-P > 5 SEC
3. LOCAL EVENT, S-P < 5 SEC
4. THOUSAND CREEK EVENT, DEPTH FIXED AT 7.5 KM
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL NOISE (SONIC)
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME
9. EMERGENT OR NOISY ARRIVALS

TABLE B4 (Continued) NW NEV 2 Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
31	197/11/32	355.1± 6.9	7.8± .7	25.9± 2.6	(15)	10	6	3,4
32	197/12/15	352.5± 6.2	8.0± .7	26.3± 2.3	(15)	11	7	3,4
33	197/19/ 7	274.8± 3.3	8.2± .5	27.1± 1.7	(15)	?	?	2
34	198/ 5/22	359.8± 6.6	7.8± .4	25.9± 1.6	(15)	10	6	3,4,9
35	198/ 5/30	358.8± 7.6	7.8± .6	25.9± 2.1	(15)	9	6	3,4,9
36	198/ 9/17	247.7± 4.2	5.8± .5	19.2± 1.9	(15)	88	55	2,9
37	198/10/18	105.5± 2.9	.3± .0	1.3± .1	(15)	?	?	6
38	198/11/15	359.8± 6.3	8.0± .7	26.5± 2.5	(15)	9	6	3,4,9
39	198/12/12	224.7± 2.4	27.2± 1.4	89.5± 4.7	(15)	?	?	1
40	198/12/17	288.7±15.7	7.5± 2.5	24.8± 8.2	(15)	98	61	2,9
41	198/16/16	356.5± 7.7	8.3± .9	27.3± 3.0	(15)	11	7	3,4,9
42	198/17/42	174.6±34.2	9.6± 3.1	31.8±10.2	(7)	128	80	2,9
43	199/15/23	333.8± 9.7	7.2± .6	23.8± 2.0	(15)	40	25	2
44	199/16/47	356.3± 6.3	7.9± .7	26.1± 2.4	(15)	9	6	3,4,9
45	199/21/50	266.8± 5.8	7.8± .9	25.8± 3.2	(15)	?	?	1,9

COMMENTS:
1. TELESEISM, FREQUENCY @ 2 HZ
2. REGIONAL EVENT, S-P > 5 SEC
3. LOCAL EVENT, S-P < 5 SEC
4. THOUSAND CREEK EVENT, DEPTH FIXED AT 7.5 KM
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL NOISE (SONIC)
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME
9. EMERGENT OR NOISY ARRIVALS

TABLE B4 (Continued). NW NEV 2 Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
46	199/23/35	121.6± 3.7	6.7± .3	22.2± 1.2	(15)	169	105	2
47	199/23/43	124.2± 5.9	6.6± .5	21.7± 1.8	(15)	169	105	2
48	200/ 7/59	356.3± 6.3	7.9± .7	26.1± 2.4	(15)	9	6	3,4,9
49	200/ 8/ 4	356.0± 6.6	8.0± .7	26.4± 2.5	(7)	10	6	3,4,9
50	200/ 8/ 9	?	?	?	(0)	57	36	2,9
51	200/10/58	164.1± 6.1	6.5± .5	21.6± 1.7	(15)	70	44	2,9
52	200/23/21	134.0± 4.5	6.3± .3	20.7± 1.1	(15)	207	129	2
53	200/23/56	78.3± .2	6.3± .0	20.9± .1	(7)	99	62	2,9
54	201/ 3/16	51.6± 5.0	7.1± .8	23.5± 2.8	(7)	17	11	3,7
55	201/10/43	293.5±16.2	20.0± 5.9	65.7±19.6	(15)	?	?	1
56	201/12/52	142.4± 2.0	6.4± .1	21.1± .5	(2)	257	160	2,9
57	201/13/29	358.2± 4.3	8.2± .5	27.2± 1.7	(15)	9	6	3,4,9
58	201/13/30	296.3±11.1	15.3± 2.8	50.2± 9.4	(15)	?	?	1
59	201/23/ 7	123.4±12.3	8.7± 1.8	28.7± 6.1	(7)	241	150	2,9
60	201/23/18	120.3± 4.8	5.9± .5	19.4± 1.9	(7)	241	150	2

COMMENTS:

1. TELESEISM, FREQUENCY @ 2 HZ
2. REGIONAL EVENT, S-P > 5 SEC
3. LOCAL EVENT, S-P < 5 SEC
4. THOUSAND CREEK EVENT, DEPTH FIXED AT 7.5 KM
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL NOISE (SONIC)
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME
9. EMERGENT OR NOISY ARRIVALS

TABLE B4 (Continued). NW NEV 2 Vector Results

EVENT	TIME day hr min	DIRECTION Azimuth	AP VEL Km/sec	AP VEL Kft/sec	No. of Vectors	DISTANCE Km	DISTANCE Mi	COMMENTS
61	202/11/ 4	204.8± 5.6	6.4± .7	21.2± 2.3	(15)	19	12	3
62	202/12/12	202.8± 9.6	42.0± 7.7	137.9±25.4	(15)	?	?	1,9
63	202/13/59	307.4±20.1	25.9± 6.0	85.0±19.7	(7)	?	?	1,9

COMMENTS:

1. TELESEISM, FREQUENCY @ 2 HZ
2. REGIONAL EVENT, S-P > 5 SEC
3. LOCAL EVENT, S-P < 5 SEC
4. THOUSAND CREEK EVENT, DEPTH FIXED AT 7.5 KM
5. EARTHQUAKE, INSUFFICIENT DATA TO LOCATE
6. CULTURAL NOISE (SONIC)
7. POOR LOCATION
8. DISTANCE UNKNOWN, NO S-P TIME
9. EMERGENT OR NOISY ARRIVALS